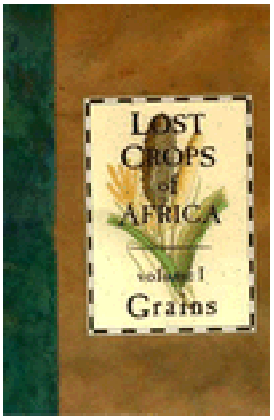

Lost Crops of Africa: Volume I: Grains

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Lost Crops of Africa

volume I

Grains

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National Research Council

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competence and with regard for appropriate balance.

The report was reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This report was prepared by an ad hoc advisory panel of the Board on Science and Technology for International Development, Office of International Affairs, National Research Council. Staff support was funded by the Bureau for Africa, Bureau for Research and Development, Office of Nutrition, and Office of Research, Agency for International Development, under Grant No. DPE-5545-A-00-8068-00.

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A NOTE FROM THE SPONSORS

For two decades, the U.S. Agency for International Development (AID) has supported various reports from BOSTID's Innovation Program. This current one, on the under exploited cereals of Africa, is particularly timely. Africa's nutrition situation is deteriorating, and this is a serious concern. Much of the population is more vulnerable to malnutrition and starvation than ever before. Clearly, the problem needs tangible and sustained support from the international community, but it also needs a host of fresh ideas.

This book offers many such ideas and is part of a commitment AID made at the International Conference on Nutrition (ICN) in December 1992. There, member countries, nongovernmental organizations, and the international community pledged to eliminate or substantially reduce starvation, widespread undernutrition, and micronutrient malnutrition within this decade.

By highlighting the broad potential for Africa's own native biodiversity to reduce the vulnerability of seriously at-risk people to food shortages, the book could become a major contributor to the ICN objectives. The so-called "lost crops" obviously can help provide food security in their native areas, which include many parts of Africa threatened with hunger. At the same time, however, maintaining the diversity of these ancient crops will protect options for the rest of the world to use.

For these and other reasons, we are pleased to have been this project's major sponsors. We hope the wealth of information in the following pages will stimulate much interest and many subsequent activities. If that occurs, the now largely overlooked resources described herein should contribute substantially toward achieving the goal of eliminating hunger and malnutrition by decade's end.

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By 1993, more than 1,000 people had participated in BOSTID's overall study of the lost crops of Africa. Most had participated by nominating species of grains, fruits, nuts, vegetables, legumes, oilseeds, spices, sweeteners, and beverage plants worthy of inclusion. In a sense, all these people were contributors to this, the first product from the study. However, the following list includes only those who provided technical details that became incorporated into various chapters of this particular book. To all the contributors, both listed and unlisted, we are truly grateful.

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Preface

The purpose of this report is to draw worldwide attention to traditional African cereals and especially to their potential for expanding and diversifying African and world food supplies. Africa is seen by many observers as a basket case—a vast region incorporating more than 40 nations that appears unlikely to be able to feed its burgeoning population in the coming years. To many observers, there seem to be no ready solutions. Some have given up hope that anything can be done.

What has been almost entirely overlooked, however, is that throughout that vast continent can be found more than 2,000 native grains, roots, fruits, and other food plants. These have been feeding people for thousands of years but most are being given no attention whatever today. We have called them the "lost crops of Africa."

Among the 2,000 lost foods are more than 100 native grasses whose seeds are (or have been) eaten. These can be found from Mauritania to Madagascar. Only a handful are currently receiving concerted research and development, and even those few are grossly underappreciated. Our goal is to demonstrate the potential inherent in these overlooked traditional cereals. Our hope is thereby to stimulate actions to increase the support for, and use of, the best of them so as to increase food supplies, improve nutrition, and raise economic conditions.

It should be understood that most of the plants described are not truly lost; indeed, a few are well known worldwide. It is to the mainstream of international science and to people outside the rural regions that they are "lost." It should also be understood that it is not just for Africa that the grains hold promise. Several of Africa's now neglected cereals could become major contributors to the welfare of nations around the world. This potential is often emphasized in the following chapters in hopes of stimulating the world community into serious and self-interested support for these species that now languish.

This study began in 1989 when the staff officers mailed questionnaires to about 1,000 scientists and organizations worldwide. The questionnaire requested nominations of little-known African food plants for possible inclusion. It contained a list of 77 native African grains, roots and tubers, vegetables, fruits, legumes, oilseeds, nuts, spices, sweeteners, and beverage plants. We anticipated that perhaps 30 of these species would prove to have outstanding merit and that the report would focus on those. What actually occurred, however, was very different.

Within a few weeks of mailing the questionnaire, replies started flooding back in numbers far greater than anticipated; many recipients photocopied their questionnaire and sent the copies (as many as 50 in several cases) on to their colleagues; requests came pouring in from people we had never heard of. The staff could barely keep up with the hundreds of requests, replies, suggestions, scientific papers, and unsolicited writings that began to appear in the mail. Within 4 months, over 100 additional species had been nominated as "write-in candidates." Within a year, at least 100 more were recommended. By then it was clear that the power of this project was far greater than anyone had foreseen. It was decided, therefore, to divide it into sections dealing individually with the different types of foods.

This report on the lost grains of Africa is the first in this series. From the flood of suggestions and information on the native African cereals was fashioned a first draft. Each of its chapters was mailed back to the original nominators as well as to other experts identified by the staff. As a result, hundreds of suggestions for corrections and additions were received, and each was evaluated and integrated into what, after editing and review, became the current text.

The report is intended as a tool for economic development rather than a textbook or survey of African botany or agriculture. It has been written for dissemination particularly to administrators, entrepreneurs, and researchers in Africa as well as other parts of the world. Its purpose is to provide a brief introduction to the plants selected and to stimulate actions that explore and exploit them. The ultimate aim is to get the most promising native African grains into greater production so as to raise nutritional levels, diversify agriculture, and create economic opportunities.

Because the book is written for audiences both lay and professional, each chapter is organized in increasing levels of detail. The lead paragraphs and prospects sections are intended primarily for nonspecialists. Subsequent sections contain background information from which specialists can better assess a plant's potential for their regions or research programs. These sections also include a brief overview of "next steps" that could help the plant to reach its full promise. Finally,

appendixes at the back of the book provide the following information:

- The addresses of researchers who know the individual plants well;
- Information on potential sources of germplasm; and
- Lists of carefully selected papers that provide more detail than can be presented here.

Because most of these plants are so little studied, the literature on them is often old, difficult to find, or available only locally. This is unfortunate, and we hope that this book will stimulate monographs, newsletters, articles, and papers on all of the species. One of the most effective actions that plant scientists and plant lovers can take is to collect, collate, and communicate the Africa-wide observations and experiences with these crops in such publications. They might also create seed supplies and distribute seeds of appropriate varieties. All this could stimulate pan-African cooperation and international endeavors to ensure that these crops are lost no more.

This book has been produced under the auspices of the Board on Science and Technology for International Development (BOSTID), National Research Council. It is a product of a special BOSTID program that is mandated to assess innovative scientific and technological advances, particularly emphasizing those appropriate for developing countries. Since its inception in 1970, this small program has produced 40 reports identifying unconventional scientific subjects of promise for developing countries. These have covered subjects as diverse as the water buffalo, butterfly farming, fast-growing trees, and techniques to provide more water for arid lands (see BOSTID Innovation Program, page 373).

Among these reports, the following provide information that directly complements the present report:

- *More Water for Arid Lands* (1974)
- *Triticale: A Promising Addition to the World's Cereal Grains* (1989)
- *Quality-Protein Maize* (1988)
- *Amaranth: Modern Prospects for an Ancient Crop* (1983)
- *Applications of Biotechnology to Traditional Fermented Foods* (1992)
- *Ferrocement: Applications in Developing Countries* (1973)
- *Neem: A Tree for Solving Global Problems* (1992)
- *Vetiver: A Thin Green Line Against Erosion* (1993).

Program and staff costs for this study were provided by the U.S. Agency for International Development. Specifically, these were

provided by the Office of Nutrition and the Office of the Science Advisor (both of the Bureau for Science and Technology), as well as the Bureau for Africa. The panel would like to acknowledge the special contribution of Norge W. Jerome, Director of the Office of Nutrition, 1988-1991, without whose initiative the project would not have been launched. Other AID personnel who made this work possible include Calvin Martin, Tim Resch, Dwight Walker, John Daly, Frances Davidson, and Ray Meyer.

General support for printing, publishing, and distributing the report has been provided by the Kellogg Endowment Fund of the National Academy of Sciences and the Institute of Medicine as well as from the Wallace Genetic Foundation. We especially want to thank Jean W. Douglas, a foundation director, for her trust and preserverance during this project's long gestation and difficult birth.

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NOTE ON TERMS

Throughout this book the word "Africa" always refers to Africa south of the Sahara. (The plants of North Africa are, biogenetically, part of the Mediterranean-Near East complex of plants, and so are mostly not native to the rest of Africa.) We have preferred to use English common names where possible, except in a few cases where they imply the plant pertains only to one country (for example, Egyptian lupin). Finally, because this book will be read and used in many regions beyond Africa, we have used the internationally accepted name "cassava" rather than its more common African name, "manioc," and "peanut" for "groundnut."

Nutritional values are in most cases presented on a dry weight basis to eliminate moisture differences between samples.

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Lost Crops of Africa

volume I Grains

Foreword

Africa has more native cereals than any other continent. It has its own species of rice, as well as finger millet, fonio, pearl millet, sorghum, tef, guinea millet, and several dozen wild cereals whose grains are eaten from time to time.

This is a food heritage that has fed people for generation after generation stretching back to the origins of mankind. It is also a local legacy of genetic wealth upon which a sound food future might be built. But, strangely, it has largely been bypassed in modern times.

Centuries ago, dhows introduced rice from Asia. In the 1500s, Portuguese colonists imported maize from the Americas. In the last few decades wheat has arrived, courtesy of farmers in the temperate zones. Faced with these wondrous foreign foods, the continent has slowly tilted away from its own ancient cereal wealth and embraced the new-found grains from across the seas.

Lacking the interest and support of the authorities (most of them non-African colonial authorities, missionaries, and agricultural researchers), the local grains could not keep pace with the up-to-the-minute foreign cereals, which were made especially convenient to consumers by the use of mills and processing. The old grains languished and remained principally as the foods of the poor and the rural areas. Eventually, they took on a stigma of being second-rate. Myths arose—that the local grains were not as nutritious, not as high yielding, not as flavorful, nor as easy to handle. As a result, the native grains were driven into internal exile. In their place, maize, a grain from across the Atlantic, became the main food from Senegal to South Africa.

But now, forward-thinking scientists are starting to look at the old cereal heritage with unbiased eyes. Peering past the myths, they see waiting in the shadows a storehouse of resources whose qualities offer promise not just to Africa, but to the world.

Already, sorghum is a booming new food crop in Central America. Pearl millet is showing such utility that it is probably the most promising new crop for the United States. Nutritionists in a dozen or more

countries see finger millet and some sorghums as the key—finally—to solving Africa's malnutrition problem. Food technologists are finding vast new possibilities in processes that can open up vibrant consumer markets for new and tasty products made from Africa's own grains. And engineers are showing how the old grains can be produced and processed locally without the spirit-crushing drudgery that raises the resentment of millions who have to grind grain every day.

That, then, is the underlying message of this book. It should not be seen as an indictment of wheat, maize, or rice. Those are the world's three biggest crops, they have become vital to Africa, and they deserve even more research and support than they are now getting. But this book, we hope, will open everyone's eyes to the long-lost promise inherent in the grains that are the gifts of ancient generations. Dedicated effort will open a second front in the war on hunger, malnutrition, poverty, and environmental degradation. It will save from extinction the foods of the forebears. And it just might bring Africa the food-secure future that everyone hopes for but few can now foresee.

NOEL D. VIETMEYER

STUDY DIRECTOR

Introduction

Africa's savannas are probably the oldest grasslands on earth and have changed little during the last 14 million years. Humans have lived there longer than anywhere else, perhaps more than 100,000 years. Grass seeds have sustained them throughout.

Indeed, gathering Africa's wild-cereal grains is probably the oldest tradition in organized food production to be found anywhere in the world. And the operation was not small. In fact, seeds of about 60 species of wild grasses are still gathered for food in Africa.[1] In earlier eras, many were ranked as staples. At least 10 of the wild grasses were domesticated and eventually produced by farmers in their fields.

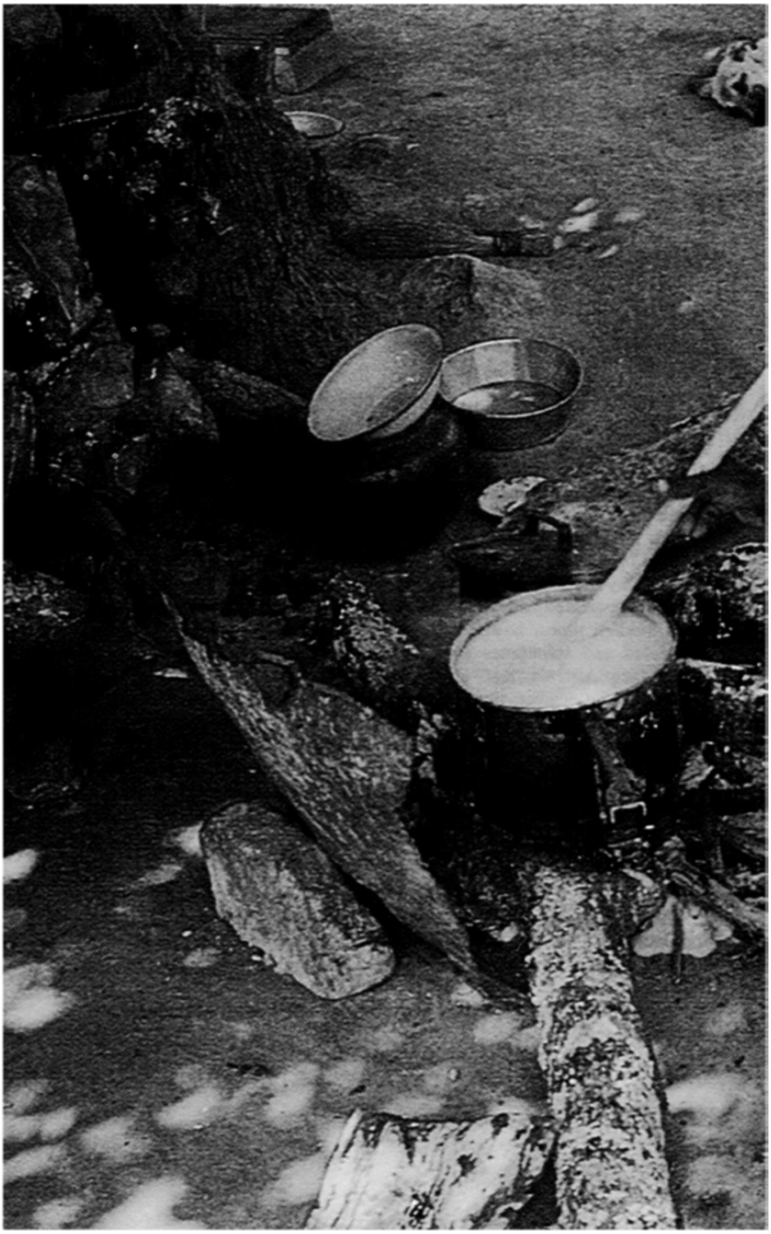
In modern times, however, this wealth of native grains has been neglected and sometimes even scorned. For this reason, we have called them Africa's "lost" grains.

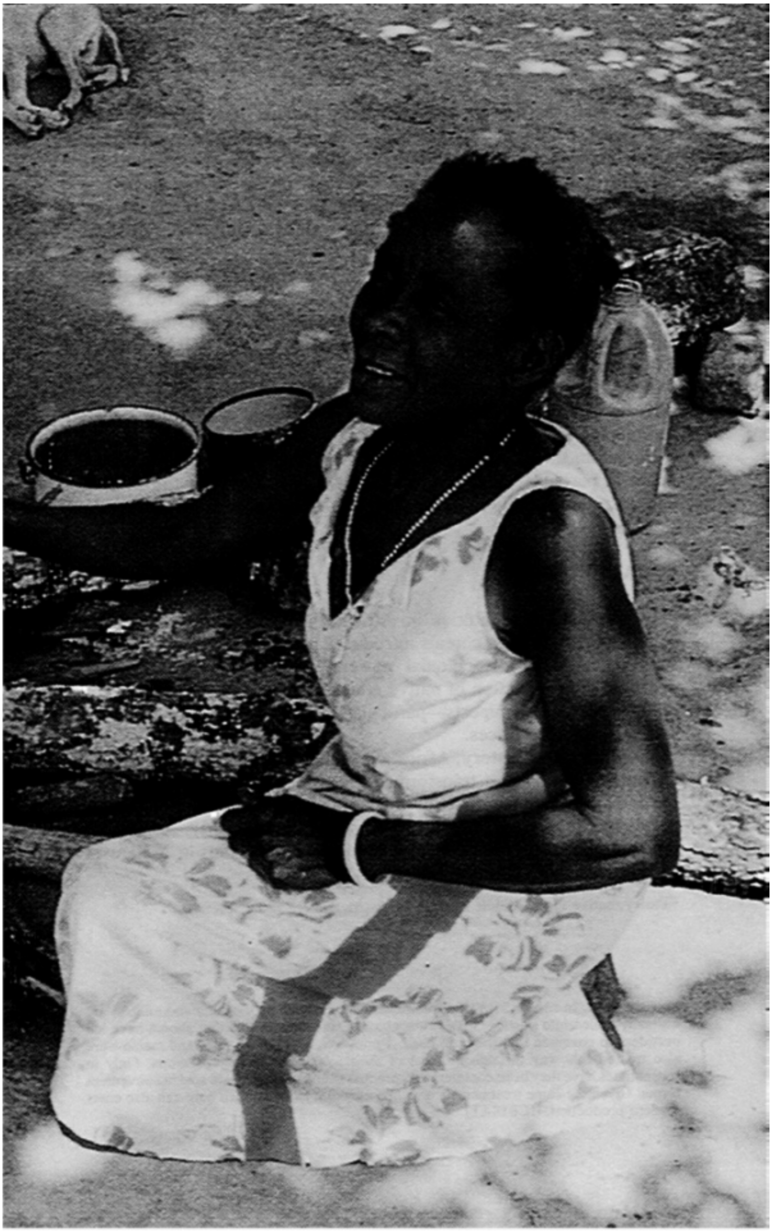
Despite the neglect, these native grains are not unworthy. For the past, for the places they were grown and for the level of support they received, they may have been appropriately judged less useful than wheat, rice, or maize. But for the time that is fast coming upon us, Africa's sorghum, millets, native rice, and other indigenous cereals seem likely to become crucial for helping to keep the world fed.

INTERNATIONAL PROMISE

The present century has seen near miraculous advances in the productivity of wheat, rice, and maize. Those top three cereals have buffered much of humanity from the disasters of overpopulation. However, the next century—when human population is expected to double—cannot be built on the expectation of redoubling the production of those three. After the year 2000, it could well be advances in today's "second

[1] Jardin, 1967.





tier" cereals that are the buffers against famine. It is they that have the greatest amount of untapped potential. Among them, Africa's native grains predominate. Sorghum and pearl millet, for instance, are the fifth and sixth most important cereals in the world, and finger millet is probably the eighth.[2] Generally, they are crops of the poorest countries, which means that their improvement could directly benefit the people in greatest need.

By comparison with modern wheat, rice, and maize—respectively from the Middle East, Asia, and Central America—the grains of Africa still retain much of the hardy, tolerant self-reliance of their wild savanna ancestors. For the future, such resilient crops will be vital for extending cereal production onto the ever-more-marginal lands that will have to be pressed into service to feed the several billion new arrivals. And if global warming occurs, they could even become vital for keeping today's best arable lands in production.

Forged in the searing savannas and the Sahara, sorghum and pearl millet in particular have the merits to become crops for the shifting and uncertain conditions of an overpopulated "greenhouse age."

LOCAL PROMISE

In the last few centuries in Africa, the local grains have been superseded by foreign cereals introduced and promoted by outsiders such as missionaries, colonial powers, or researchers. In recent decades, the production of native grains has plunged even further as millions of tons of imports—particularly wheat and rice—have been sold at subsidized prices.

Despite its long history, Africa's cereal production is now low. The Green Revolution that transformed the tropics and subtropics, from the Indian subcontinent to South America, passed Africa by. In fact, per-capita production of cereals has decreased nearly 20 percent (present annual output being only about 50 million tons or a mere 11

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[2] Barley, native to the Middle East, is the fourth and rye is the seventh.

In rural Africa, the traditional cereals, such as sorghum and millets, are normally boiled into porridges (thick) or gruels (thin). Scenes like that shown have led outsiders to conclude that the crop itself is primitive. But wheat, rice, and maize were also treated this way throughout most of their 5,000-year history as crops. Only in recent times have they been commercially processed and packaged and sold in convenient forms. Given the same treatment, grains like sorghum being cooked here can also enter modern production. (ICRISAT)

kg per person). It has been estimated that Africa now needs 14 million tons more grain each year than it is producing. With the population growing at 3 percent per year and agricultural production increasing by only 2 percent, that shortfall will reach 50 million tons by 2000.[3]

Obviously a crisis is impending in Africa's food supply. Improving cereals for Africa should be a great international agricultural endeavor. Maize, rice, and wheat have much to offer and deserve greatly increased support. A crucial objective, though, must be to extend cereal production into areas where environmental stresses and plant diseases currently limit their growth. For these now-marginal lands, Africa's own grains offer outstanding promise. They are tools for helping build a new and stronger food-production framework—one of inestimable value for the hungriest and most destitute nations.

THE SPECIES

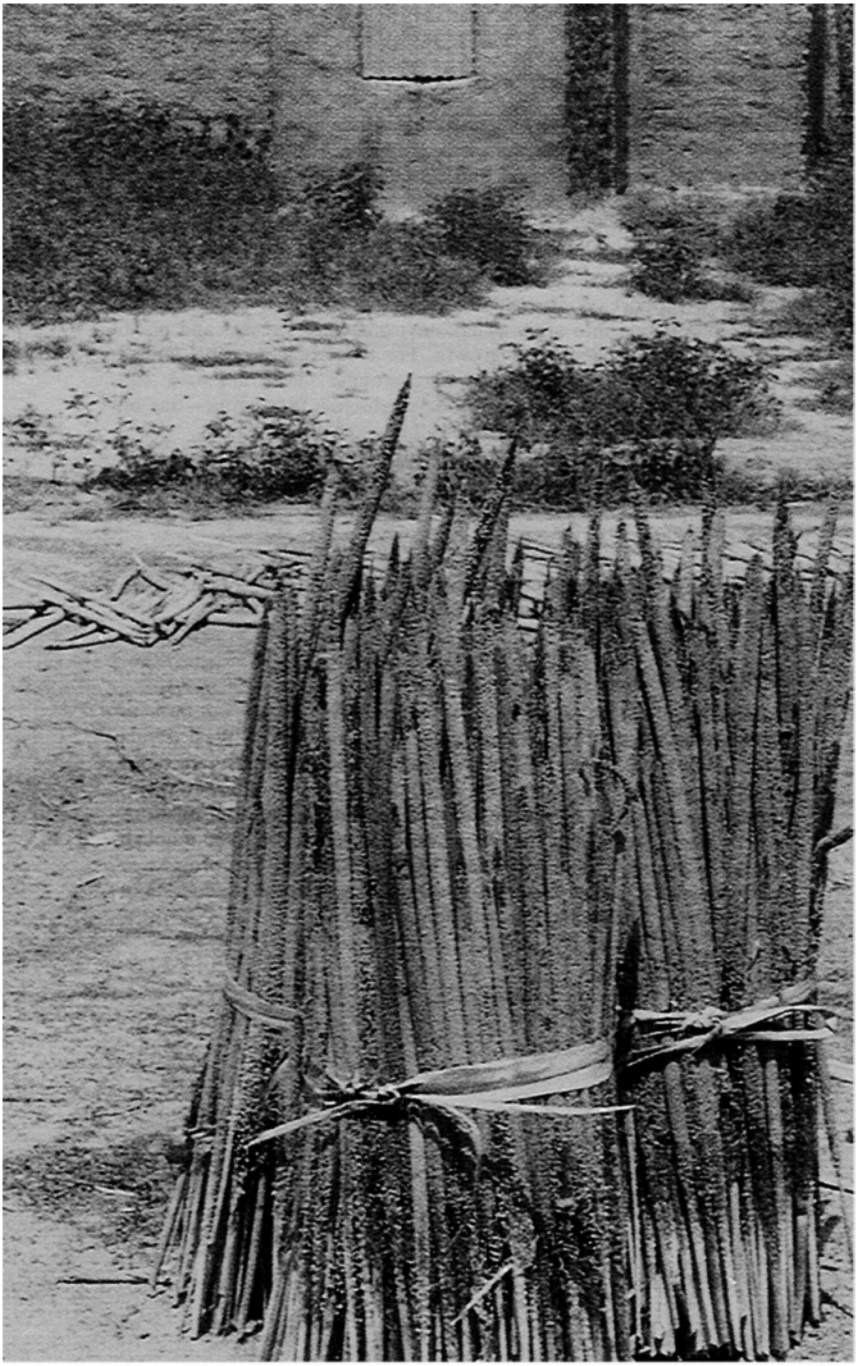
This promise (and much more) is described in the body of this book. There, the following species are covered in detail.

African Rice

Most people think of rice as an exclusively Asian crop, but farmers have grown a native rice (*Oryza glaberrima*) in parts of West Africa for at least 1,500 years. This crop comes in a wealth of different types that are planted, managed, prepared, and eaten in different ways. Some mature extremely quickly and will fit into seasons and situations where other cereals fail. The grain is much like common rice, although the husk around it is usually red. This plant not only has promise in its own right, its genes might also eventually benefit the production of common rice worldwide. (See chapter 1, page 17.)

[3] Spore, June 1995.

Pearl millet in Mali, as seen in the vicinity of Mopti. Crops such as this are a mainstay of life in the vast rural regions of Africa. Despite their vital importance to millions like this village farmer, traditional cereals receive only minuscule support from science and the world community. They are the "forgotten end" of agricultural development. Yet, as can be seen here, they are a part of the heritage and daily living of hard-working Africans. Outsiders may scorn pearl millet, but this woman's face shows the pride she feels in her harvest. (H.S. Duggal, courtesy ICRISAT)



Finger Millet

In parts of East and Central Africa (not to mention India), millions of people have lived off finger millet (*Eleusine coracana*) for centuries. One of the most nutritious of the major cereals, it is rich in methionine, an amino acid critically lacking in the diets of hundreds of millions of the world's poor. The plant yields satisfactorily on marginal lands, and its tasty grain is remarkable for its long storage life. The fact that certain Africans thrive on just one meal a day is attributed to the nutritive value and "filling" nature of this grain. (See chapter 2, page 39.)

Fonio (Acha)

An indigenous West African crop, fonio (comprising two species, *Digitaria exilis* and *Digitaria iburua*) is grown mainly on small farms for home consumption. It is probably the world's fastest maturing cereal and is particularly important as a safety net for producing when other foods are in short supply or market prices are too high for poor people to afford. But fonio is much more than just a fallback food; it is also a gourmet grain. People enjoy it as a porridge, in soups, or as couscous with fish or meat. The plant grows well on poor, sandy soils. It, too, is rich in the amino acid methionine. It also has a high level of cystine, a feature that is an even rarer find in a cereal. With its appealing taste and high nutritional value, this could become a widespread gourmet grain for savanna regions, perhaps throughout much of Africa or even much of the world. It might well have a big future as a cash crop and export commodity. (See chapter 3, page 59.)

Pearl Millet

Some 4,000 years ago, pearl millet (*Pennisetum glaucum*) was domesticated from a wild grass of the southern Sahara. Today, it is the world's sixth-largest cereal crop, but it has even greater potential than most people imagine. Of the major cereals, pearl millet is the most tolerant of heat and drought; it has the power to yield reliably in regions too arid and too hot to consistently support good yields of other major grains. These happen to be the regions that will most desperately need help in the decades ahead.

Already, water is shaping up as the most limiting resource for numerous economies—even some of the most advanced. Agriculture is usually a country's biggest user of water. Thus, for nations that have never heard of it or that perhaps regard it with scorn, pearl millet might quickly rise to become a vital resource. (See chapters 4-6; pages 17, 93, and 111.)

Sorghum

Globally speaking, sorghum is the dietary staple of more than 500 million people in more than 30 countries. Only rice, wheat, maize, and potatoes surpass it in the quantity eaten. For all that, however, it produces merely a fraction of what it could. Indeed, if the twentieth century has been the century of wheat, rice, and maize, the twenty-first could become the century of sorghum (*Sorghum bicolor*).

First, sorghum is among the most photosynthetically efficient and quickest maturing food plants. Second, it thrives on many marginal sites where other cereals fail. Third, sorghum is perhaps the world's most versatile food crop. Some types of its grains are boiled like rice, cracked like oats for porridge, "malted" like barley for beer, baked like wheat into flat breads, or popped like popcorn for snacks.

The plant has many uses beyond food as well. Perhaps the most intriguing is its use for fuel. The stems of certain types yield large amounts of sugar, almost like sugarcane. Thus, sorghum is a potential source of alcohol fuels for powering vehicles or cooking evening meals. Because of the plant's adaptability, it may eventually prove a better source of alcohol fuel than sugarcane or maize, which are the only ones now being used.

Finally, sorghum is a relatively undeveloped crop with a truly remarkable array of grain types, plant types, and adaptability. Most of its genetic wealth is so far untapped and even unsorted. Indeed, sorghum probably has more undeveloped genetic potential than any other major food crop in the world. (See chapters 7-11; pages 127, 145, 159, 177, and 195.)

Tef

This staple cereal (*Eragrostis tef*) is the most esteemed grain in Ethiopia. It is ground into flour and made into pancake-like fermented bread, *injera,* that forms the basic diet of millions. Many Ethiopians eat it several times a day (when there is enough), particularly with spicy sauces, vegetables, and stews.

Tef is nutritious; the grain is about 13 percent protein, well balanced in amino acids, and rich in iron. In many ways, it seems to have ideal qualities for a grain, yet research has been scanty and intermittent, and so far the crop is all but unknown beyond Ethiopia. In the last few years, however, commercial production has started in the United States and South Africa, and an export trade in tef grain has begun. These seem likely harbingers of a new, worldwide recognition of this crop. (See chapter 12, page 215.)

MISUNDERSTANDINGS

It is fair to ask why Africa's grains are not better known. At least in part, the reason can be attributed to several unjustified perceptions. Some of these misperceptions that are clouding the world's vision of Africa's native grains are discussed below.

Inferiority of Displaced Crops. Introduced crops have displaced several African ones over the past few centuries. For example, in several areas maize has replaced sorghum; in West Africa, Asian rice has replaced African rice. As a result, there is a strong inclination to consider the introduced crop superior and the native crop obsolete and unworthy of further development.

This is illogical, ill-conceived, and even dangerous. All the world's agriculture is dynamic and every crop gets displaced at certain times and certain places. In much of the eastern United States, for instance, wheat was long ago displaced by soybeans; in the Southeast, peanuts replaced rice; and in the Great Plains, wheat has supplanted maize. But no one in America considers wheat, maize, or rice to be inferior, obsolete, or unworthy.

Misclassification. Africa's cereals are inadvertently discriminated against through the way they are described. People everywhere classify sorghums and millets in a different light from wheat, rice, and maize. All the categories have pejorative connotations. For instance, these grains are typically referred to as:

- "Coarse" grains (that is, not refined; fit for animal feed);
- "Minor" crops (not worthy of major status);
- "Millets" (seeds too small);
- "Famine" foods (good for eating only when starving); and
- "Feed" grains (suitable for animals only).

Poor People's Plants. Many crops are scorned as fit only for consumption by the poor. It happens everywhere. Peanuts, potatoes, and other common crops once suffered from this same discrimination. In the United States the peanut was considered to be "merely slave food" until little more than a century ago, and in the 1600s the English refused to eat potatoes because they considered them to be "Irish food." Cultural bias against peasant crops is a tragedy; the plants poor people grow are usually robust,

productive, self-reliant, and useful—the very types needed to feed the hungriest mouths on the planet.

Inferior Yield. Low yield is perhaps the most frequent comment made about Africa's grains. Yet these grains are now mostly cultivated in marginal lands under less than optimal management and the yields therefore do not reflect their true potential.

Moreover, the use of yield figures can be totally misleading. Maize may be able to outyield finger millet, pearl millet, hungry rice, and tef, but only when soil fertility, moisture, and other conditions are good. Under poor conditions, African grains often outyield the best products of modern science.

Unworthy Foods. Millets are mainly used for making porridges, fermented products, couscous, and other foods that are alien and therefore somewhat suspect to non-Africans, especially Westerners. This has led outsiders, who often serve as "decision makers," to direct resources away from native grains.

Disparaging comments about African foods are not uncommon in the writings of travelers—especially in Victorian times. They are of course only personal—often highly prejudiced—opinions but, lingering in the literature, they have a pernicious influence that can last for decades or even centuries. Europeans treated the potato and tomato this way when they first arrived from the Americas. Myths about taste and safety helped block the adoption of both for two centuries.

Cost-Effectiveness. Most of Africa's grains are exclusively subsistence crops; the remainder are partially so. Farmers grow them for their own use rather than for market, and therefore there are no statistics on production or costs. A plant may be helping feed millions, but in the international figures on area sown, tonnage produced and exported, and prices paid it never shows. It is as if it doesn't exist.

This situation might be of little consequence were it not for the fact that economic-development funding these days is overwhelmingly judged on "cost-effectiveness." Thus, a crop with no baseline data is at a cruel disadvantage. Maize or wheat researchers can pull out impressive figures to justify the promise of their proposed studies. Finger millet or fonio researchers can only come up with guesses. To the hard-pressed, cost-conscious administrator—ever fearful of accusations that public funds may be misspent—the decision on which proposal to support is inevitably biased.

Other Cultivated Grains

Some of the cereals described previously are not, strictly speaking, "lost." But there are a number of African food grains that are indeed truly overlooked by modern science. (See chapter 13, page 237.)

Guinea Millet

Perhaps the world's least-known domesticated cereal, guinea millet (*Brachiaria deflexa*), is cultivated by farmers only in the Fouta Djallon Plateau, a remote region of Guinea. At present, almost nothing can be said about its potential, but it clearly deserves exploratory research and support.

Emmer

This rare wheat (*Triticum dicoccum*) originated in the Near East, but it has a very ancient African heritage. It reached Ethiopia probably 5,000 years ago or more and, although it virtually disappeared elsewhere in the world, it comprises almost 7 percent of Ethiopia's entire wheat production. Moreover, far from abandoning it, Ethiopian farmers over the last 40 years have actually increased the percentage of emmer that they grow.

The plant is adapted to a wide range of environments and should be producible in many parts of the world. The fact that it is little changed from wheat eaten in the times of the Bible and the Koran could give it special consumer appeal. But it can stand on its own culinary merits. It is one of the sweetest and best-tasting cereals.

Irregular Barley

Although barley is also not native to Africa, it, too, has been used in Ethiopia for thousands of years. Indeed, Ethiopian barley has been isolated so long that it has been given its own botanical name, *Hordeum irregulare,* and has developed its own genetic "personality." This ancient barley is grown mainly in Ethiopia, where it ranks fourth among crops, both in production and area. Throughout most of the upper highlands it accounts for over 60 percent of the people's total plant food. Ethiopia is perhaps unmatched with respect to barley diversity. Indeed, some scientists think it is a source of new germplasm that could possibly boost barley growing in Africa and around the world.

Ethiopian Oats

In Ethiopia is found a native oats, *Avena abyssinica.* This species was domesticated in the distant past and is a largely nonshattering plant that retains its grain so people can harvest it. It has long been used in Ethiopia and is well adapted to the high elevations there. It is, however, unknown elsewhere.

Wild Grains

As noted, people in Africa have been eating wild grains for perhaps 100,000 years. In modern times, however, various writers have discounted these grains as mere "scarcity foods." This is obviously wrong: wild grains were eagerly eaten even when pearl millet, for one, was abundant.

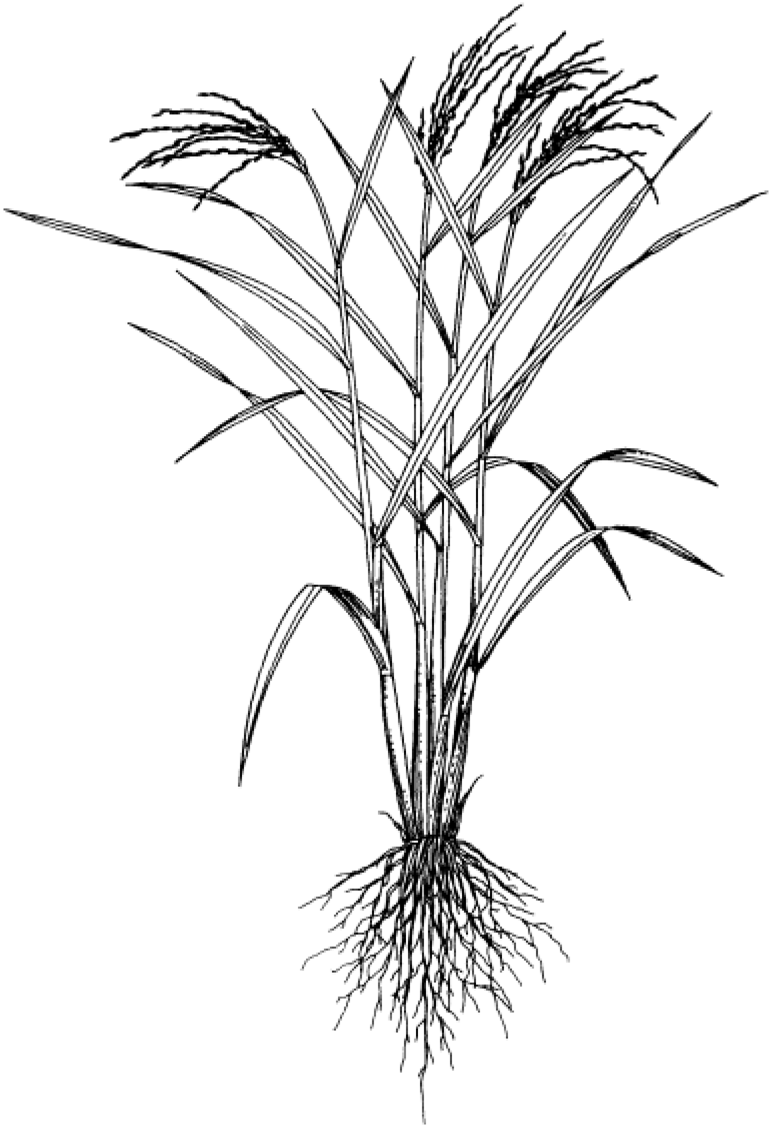
Many modern writers also imply that the wild cereals were gathered only on a small and localized scale. This, too, is apparently false. The harvest in the Sahara, for example, was large-scale, sophisticated, commercial, and much of it was export-oriented. The wild grains were a delicacy that even the wealthy considered a luxury. Examples of such untamed cereals are drinn, golden millet, kram-kram, panic grasses, wild rices, jungle rice, wild tefs, and crowfoot grasses.

Resurrecting the grain-gathering industry of the past might be a way to help combat desertification, erosion, and other forms of land degradation across the worst afflicted areas of the Sahel and its neighboring regions. A vast and vigorous grain-gathering enterprise might perhaps provide enough economic incentive to ensure that the grass cover is kept in place and that overgrazing is controlled. That would bring environmental stability to the world's most alarming case of desertification. (See chapter 14, page 251.)

CONCLUSION

These "lost" plants have much to offer, and not just to Africa. Indeed, they represent an exceptional cluster of cereal biodiversity with particular promise for solving some of the greatest food-production problems that will arise in the twenty-first century.

This potential for utility in the future is because Africa's native grains tend to tolerate extremes. They can thrive where introduced grains produce inconsistently. Some (tef, for instance) are adapted to cold; others (pearl millet, for example) to heat; at least one sorghum to waterlogging; and many to drought. Moreover, most can grow better than other cereals on relatively infertile soils. For thousands of years they have yielded grain even where land preparation was minimal and management poor. They combine well with other crops in mixed stands. Some types mature rapidly. They tend to be nutritious. And at least one is reputed to be better tasting than most of the world's well-known grains.



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African Rice

To most of the world, rice connotes Asia and the vast agriculture of Far Eastern river deltas. Indeed, humanity's second major crop *is* from Asia, and 90 percent of it—the main source of calories for 2.7 billion people—is grown there.

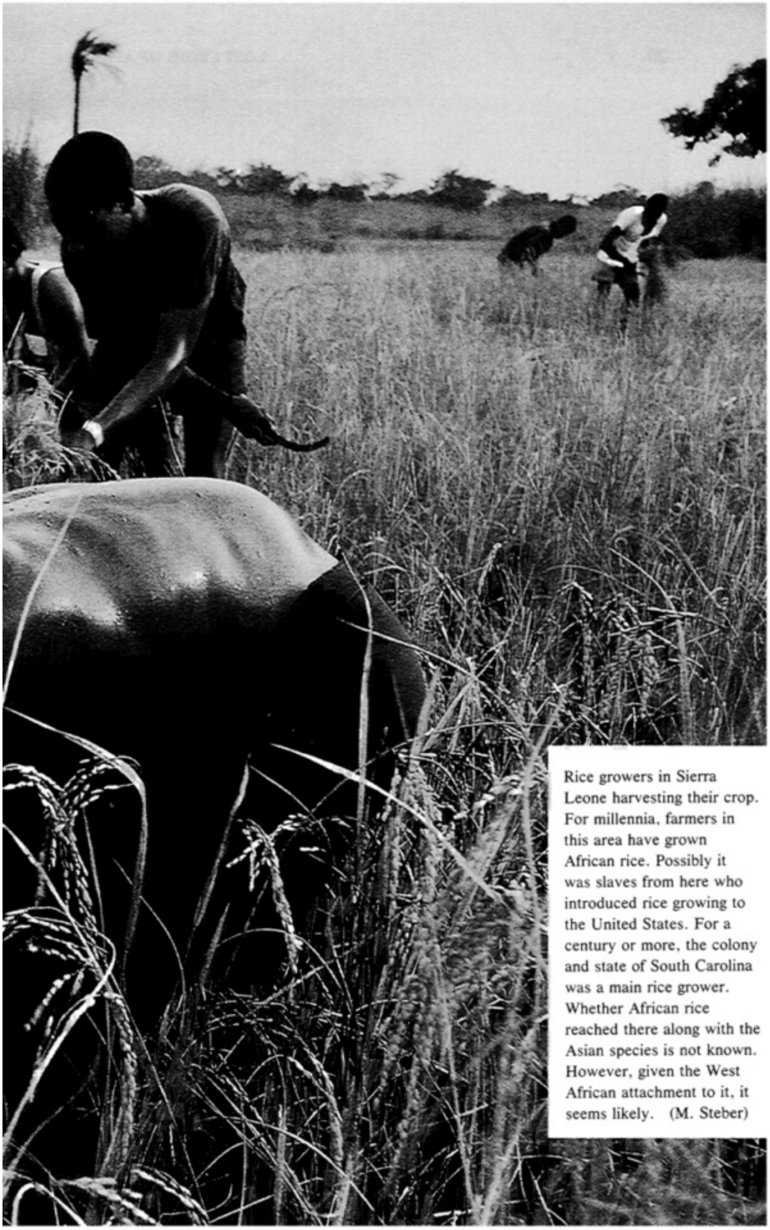
But rice is also African. A different species has been cultivated in West Africa for at least 1,500 years. Some West African countries have, since ancient times, been just as rice-oriented as any Asian one. For all that, however, almost no one else has ever heard of their species.[1]

Asia's rice is so advanced, so productive, and so well known that its rustic relative has been relegated to obscurity even in Africa itself. Today, most of the rice cultivated in Africa is of the Asian species. In fact, the "great red rice of the hook of the Niger" is declining so rapidly in importance and area that in most locations it lingers only as a weed in fields of its foreign relative. Soon it may be gone.

This should not be allowed to happen. The rice of Africa (*Oryza glaberrima*) has a long and noteworthy history. It was selected and established in West Africa centuries before any organized expeditions could have introduced its Asian cousin (*Oryza sativa*). It probably arose in the flood basin of the central Niger and prehistoric Africans carried it westward to Senegal, southward to the Guinea coast, and eastward as far as Lake Chad. In these new homes, diligent people developed it further.

Like their counterparts in the Far East, Africa's ancient rice farmers selected a remarkable range of cultivars suited to many types of habitats. They produced "floating" varieties (for growing in deep

[1] There are rice relatives in other parts of the world, too. The genus *Oryza* is among the most ancient grasses and was able to spread to every continent before they drifted too far apart. The result is that different *Oryza* species are strung out over the tropical regions of the globe, including South America and Australia. Only one species in Asia and one in Africa were domesticated, however.



Rice growers in Sierra Leone harvesting their crop. For millennia, farmers in this area have grown African rice. Possibly it was slaves from here who introduced rice growing to the United States. For a century or more, the colony and state of South Carolina was a main rice grower. Whether African rice reached there along with the Asian species is not known. However, given the West African attachment to it, it seems likely. (M. Steber)

water), weakly and strongly photoperiod-sensitive types (for growing in different latitudes and seasons), swamp and upland cultivars (for growing under irrigated and rainfed conditions, respectively), and early and late-maturing types. And, for all of these, they selected forms with various seed characteristics.

Although modern efforts to expand rice production in Africa have largely ignored this indigenous heritage, African rice is still cultivated in West Africa—especially in remote districts. There, until recently, much of it was reserved as a special luxury food for chiefs and religious rituals. Today, however, farms that grow substantial stands of African rice are few. The area of most intense cultivation is the "floating fields" on the Sokoto fadamas (floodplains) of Nigeria and the Niger River's inland delta in Mali. However, the crop is also widely, if thinly, spread in Sierra Leone (see box, page 28) and neighboring areas, as well as in the hills that straddle the Ghana-Togo border.

From one point of view, there seem to be good reasons for abandoning this food of the forebears. In most locations farmers prefer the foreign rice because it yields better and scatters less of its seed on the ground. Millers prefer it because its grain is less brittle and therefore easier to mill. Shippers prefer it as well. For them, African rice is hardly worth a minute's consideration because it is not a trade commodity and most types are red-skinned and therefore unsuitable for mixing with conventional rice in bulk handling.

But these are concerns almost entirely of commercial farming. The situation is quite different where rice is grown strictly for localized, subsistence, or specialty use. There, yield, brittleness, color, or international interest can be unimportant. Indeed, small-scale farmers often prefer African rice. They like the grain's taste and aroma, and even its reddish appearance. They find the plant easy to produce: its rambunctious growth and spreading canopy help suppress weeds and it generally resists local diseases and pests by itself. Also, to some people traditional rituals are meaningless unless the ancient grain is employed.

Moreover, these are not the only advantages. Compared to its Asian cousin, African rice is better at tolerating fluctuating water depths, excessive iron, low levels of management, infertile soils, harsh climates, and late planting (a valued feature because in West Africa's erratic

For hundreds, if not thousands, of years, "floating" versions of African rice have been cultivated beside the Niger River, especially here between Timbuktu and Gao. Farmers along this 600-km stretch count on the Niger to overflow its banks and flood the lowlands where they've sowed their seeds. The rice plants can survive in rising floodwater up to several meters deep. When drought reduced the Niger's flow in the 1970s, the full crop could not be planted and a million lives were put at risk. (J. Gallais. courtesy Flammarion et cie, Paris)

climate the rains are often tardy). Also, there are some types that mature much more quickly than common rice. Planted out in emergencies when food stocks are getting low, these can save lives.

PROSPECTS

What actually happens in the future to this interesting African crop will depend on individual initiatives, most of them within Africa itself. Part of the problem is its lack of prestige. Everywhere, consumers have fallen in love with processed Asian rice. If someone now makes a processed (that is, parboiled) product out of African rice, that alone may return it to high favor. Indeed, it may rise to become a gourmet food of particular interest because of its ancient and historic heritage.

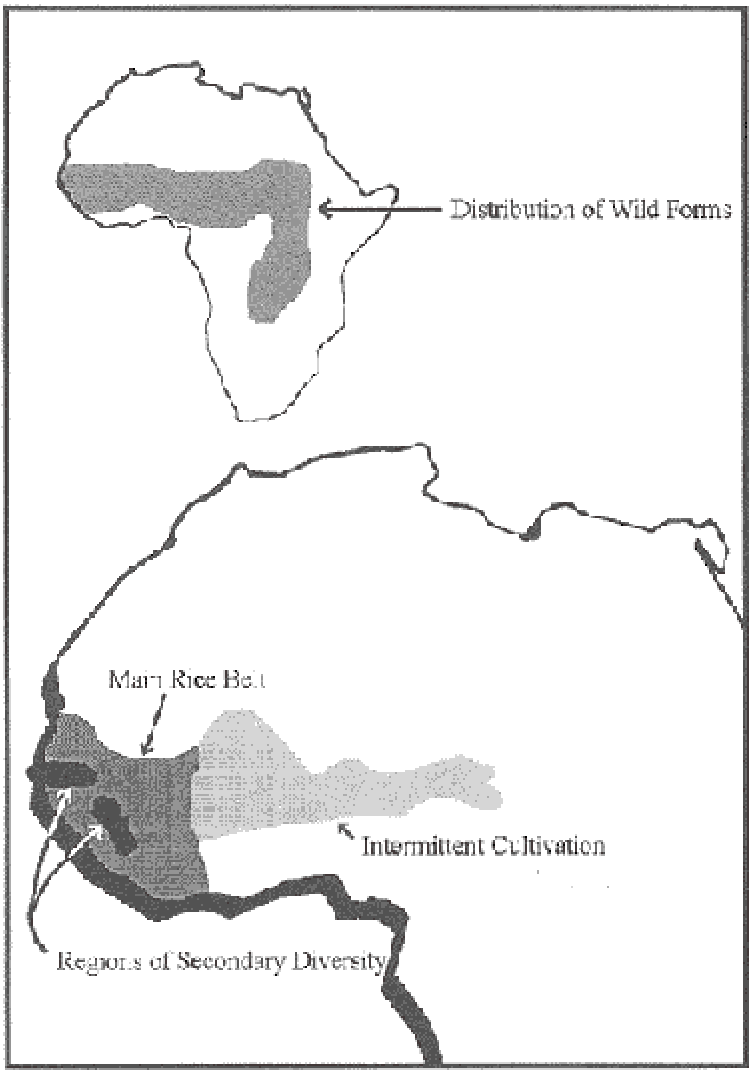
Part of the problem, also, is lack of supply. Thus, if such specialty markets develop, it seems likely that African rice will survive as a commercial crop. Then, with selection and breeding, its various cultivars can almost certainly be made to compete with Asian rice in most African locations. There is evidence, for example, that certain types already match the productivity of Asian rice, and in the yield figures there is considerable overlap between the best African and the poorer Asian ones. This is remarkable considering the 5,000 years of intense effort that has been invested in improving Asian rice.

Even if the local rice never thrives as a commercial crop, it will likely continue as a subsistence crop in West Africa. However, whether this is a lingering decline for a few more decades or a robust return to massive use depends on the responses of scientists, administrators, and others. Even in its current neglected form the plant has something to offer, but just a small amount of support, promotion, and practical research seems likely to bring dramatic improvements.

The problems of shattering and brittle grain can undoubtedly be overcome by careful scrutiny of the types already spread across West Africa. A small cash prize might well produce appropriate genotypes almost overnight. The same could happen for white-skin types, which many people would find more appealing than the main type of today. Even now, not all the varieties are red-skinned. In Guinea, Senegal, and the Gambia, for example, white types are said to be already available.

Africa

Although no one can be certain of what will happen with this crop in the coming decades, the prospects for doubling its production and overcoming its various technical limitations are good. Technical



Rice was cultivated in Africa long before any navigator from Java or Arabia could have introduced their kind of rice to Madagascar or the East African coast. The native rice was grown first in the central Niger delta, and later in the Gambia, Casamance, and Sokoto basins. African rice is now utilized particularly in the central Niger floodplain, the coastal zone between Senegal and Sierra Leone, and the mountainous areas of Guinea and the Ghana/Togo border.

The primary center (small map) shows the distribution of the wild form. The secondary centers are where notable arrays of cultivated types occur. The main rice belt is the zone where African rice is cultivated the most.

improvements, such as those just mentioned, could give it a solid future. It is now known only in West Africa, but eventually it might also find a place elsewhere. Although only a few African countries grow even Asian rice in a major way, it is the continent's fourth biggest cereal (after maize, pearl millet, and sorghum) in terms of area planted. And demand is ever rising as population, standards of living, urbanization, international travel (with its exposure to new cuisines), and the search for easy-to-prepare foods increase. At present, West Africa absorbs a quarter of the world's rice exports.

Humid Areas

On the face of it, African rice is at its biggest disadvantage in the humid lowlands. This is prime country for growing Asian paddy rice, whose current competitive edge makes it clearly the crop of choice. In addition, in this zone farmers and governments often invest in irrigation facilities, and to recoup their vast expenditures they must grow the highest yielding, highest selling crop. As a result, it is in this zone that African rice has suffered its most precipitous decline.

On the other hand, even here there seems to be a small but vital place for African rice. A recent survey in southern Sierra Leone, for example, found that even where Asian rice predominates farmers still retain one or two ultra-quick traditional types as "hunger-breakers." And, faced with a worsening hungry season caused by economic recession or other factors, many farmers say they would revert to the short-duration African-rice varieties, if only they could find sources of seed.[2]

Dry Areas

For the truly arid zones African rice is not a suitable crop, but on moderately watered sites (for example, where annual rainfall is at least 760 mm) or seasonally flooded sites its prospects seem good. The fact that some varieties mature 10-20 days before their principal Asian-rice rivals is significant in drylands where precipitation is often erratic. In northern Sierra Leone, for example, the rainy season in recent decades has been terminating early and with unusual abruptness. For this reason alone, farmers are cultivating African rice on at least some portion of their land.[3] With it, they are assured of a harvest.

Upland Areas

In West Africa's highlands[4] where this type of rice is still an important grain producer, it will continue to be important as

[2] Information from P. Richards. For additional details, see box, page 28. Two Sierra Leone varieties, *pende* and *mala,* ripen within 90-110 days: *pende* is a strongly tillering variety valued also for its ability to smother weeds.

[3] Information from P. Richards.

[4] By most standards, these lands are not very high—only about 1,000 m above sea level.

a subsistence crop. The upland varieties are notably useful in shifting agriculture. They also have a place in crop rotations because their root systems and susceptibility to soilborne diseases differ from those of the major crops. Planting them for a season or so tends to "sanitize" the site.

Other Regions

For lands beyond Africa, prospects are slight. There, African rice offers few benefits over the Asian species and may not adapt well.[5] Although it might have a future as a small specialty crop, more likely it will become an accursed weed, especially in rice fields.

USES

African rice can be used for all the same purposes as Asian rice. It is thus extremely versatile. There are, however, some specialized local uses. West Africa's Mandingo and Susu people, for instance, use rice flour and honey to make a sweet-tasting bread, so special that it is the centerpiece of ceremonial rituals. Rice beer is popular throughout West Africa, and in Nigeria a special beer (called *betso* or *buza*) is made from rice and honey. Also, in Ivory Coast there is a project to use African rice as a component of baby foods.

NUTRITION

Both rices are principally carbohydrate sources. However, in practice African rice's nutritional quality is greater than that of Asian rice.[6] This seems to be not because of any inherent difference but because it is more difficult to polish. Asian rice is invariably polished to a greater degree, and therefore more of its nutrients (especially the important vitamin, thiamine) are lost.

AGRONOMY

As with Asian rice, African rice is grown in three major ways: dryland (or upland), paddy, and "floating."

[5] For instance, one reason why African rice is not better known internationally is that it grows poorly in the Philippines, where the world's major rice-research facility is located. This is not a measure of inferiority—just a lack of adaptation to the local conditions, especially to viral diseases.

[6] Information from the Food and Nutrition Board, Food Research Institute, Ghana.

Dryland

About 40 percent of the rice production in Africa's 15 major rice-producing countries relies on rain as the only source of water. Almost all of that area employs the Asian species, but West Africa still grows a small but significant amount of dryland African rice. Indeed, in certain parts of Ghana and Togo it is the chief staple.

The dryland form thrives in light soils wherever there is a rainy season of at least 4 months and minimum rainfall of 760 mm. It is often interplanted with millets, maize, sorghum, beniseed, roselle, cowpea, cassava, or cotton. Today's varieties mature in 90-170 days. Yields average 450-900 kg per hectare, but can go as high as 1,680 kg per hectare.

Paddy

Only about one-sixth of Africa's rice is produced using irrigation and 60 percent of that is in just one country—Madagascar. Swamp rice, however, is being increasingly cultivated in former mangrove areas of the Gambia, Guinea-Bissau, Guinea, and Sierra Leone. Essentially all of it at present is the Asian species.

African rice can also be grown in the same way. It can be seeded into damp soil or transplanted to fields under water. These types mature in 140-220 days. The yield ranges from 1,000 to 3,000 kg per hectare.[7]

Floating

In the River Niger's inland delta in Mali, farmers grow various forms of floating African rice. These plants lengthen prodigiously to keep their heads at the surface of the floodwaters, where they flower and set seed. One type (*songhai tomo*) can grow in water more than 3 m deep.

Floating varieties can utilize deeply inundated basins where nothing else can be raised. They are often harvested from canoes. They ripen in 180-250 days. Yields range from 1,000 to 3,000 kg per hectare, depending on the amount of rainfall early in the growing season and on the eventual depth of the subsequent floods.

HARVESTING AND HANDLING

African rice is handled like its more famous Asian cousin, but (as noted) its grains tend to split, and so greater care must be taken. Also, it is more difficult to hull.

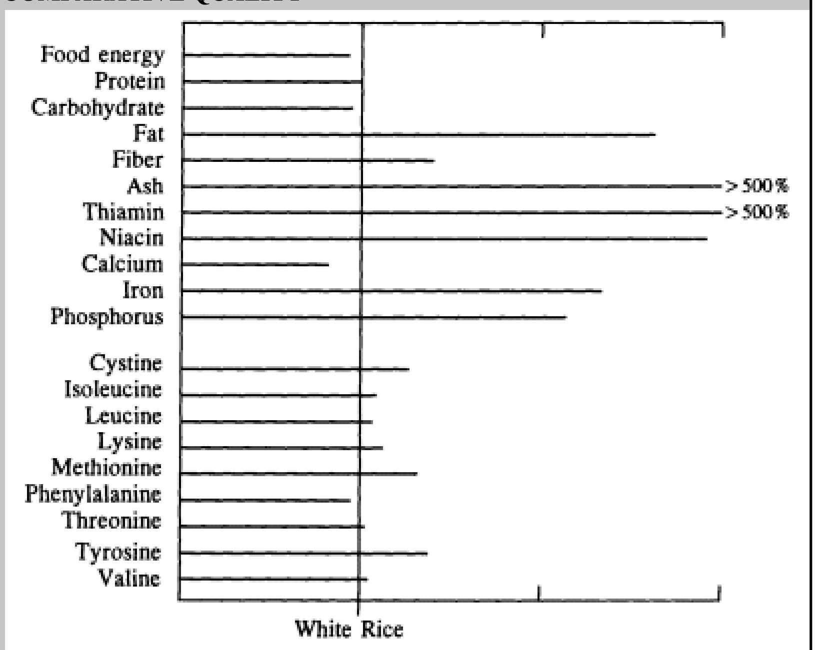
As is to be expected with such a neglected crop, yields are variable and uncertain. However, there are hints that they are not as low as

[7] In the region of Timbuktu a very promising, nonfloating, dwarf type called *riz kobé* is grown on runoff water in the rainy season. (Information from W. Schreurs.)

NUTRITIONAL PROMISE

Main Components		Essential Amino Acids	
Moisture (g)	5	Cystine	2.6
Food energy (Kc)	358	Isoleucine	4.7
Protein (g)	7.6	Leucine	8.8
Carbohydrate (g)	81	Lysine	4.1
Fat (g)	1.9	Methionine	3.1
Fiber (g)	0.5	Phenylalanine	5.1
Ash (g)	3.8	Threonine	3.7
Thiamin (mg)	0.39	Tyrosine	4.6
Niacin (mg)	5.0	Valine	6.4
Calcium (mg)	25		
Iron (mg)	2.0		
Phosphorus (mg)	263		

COMPARATIVE QUALITY



A glance at this chart shows that whole-grain African rice is at least as rich as white (i.e., Asian) rice in most nutrients. In some vitamins and minerals it is far superior.

commonly claimed. For example, five years of experiments at two sites in Ivory Coast found that 16 populations of African rice (selected for their productivity) compared favorably with three top varieties of Asian rice. Despite their natural lodging and spontaneous shattering, the best African rice varieties (BG 141 and BG 187) gave average and remarkably stable yields of 1,500-1,800 kg per hectare (depending on the site) as did their Asian counterpart (Moroberekan), the traditional upland variety promoted in Ivory Coast.[8]

RICE IN SIERRA LEONE

Recently, researchers surveyed the distribution and use of rice in Sierra Leone. Following is their account of their findings. It is probably indicative of the situation throughout much of West Africa.

In visits to just over 500 farmers in all parts of Sierra Leone, we found that 245 types ("varieties") of rice were in use. Of these, 24 were African rice.

Although it generally yields less than Asian rice, African rice survives —and may even be making a modest comeback in some areas, especially in the drier northwest. There are a number of reasons for this. Compared with Asian rice, African rice:

- Seems to manage better on extremely impoverished soils.
- Competes better with weeds. Indeed, farmers pressed by labor shortages leave the crop to fend for itself. African rice will yield something even where Asian rice is choked out of existence by weeds. This is important because for small-scale rice farmers labor shortage is *the* most pressing constraint.
- Matures quicker. Nearly all the samples we collected matured in 100-125 days and are therefore among the quickest ripening rice cultivars in the country. (The average for dryland Asian rice in our sample was 130-140 days, and for wetland, 160-170 days.)
- Is preferred by many of the people. Several informants believed that African rice is nutritionally superior. They say that it is "heavy in the stomach" and keeps hunger at bay far longer

[8] Clement and Goli, 1987. In most cases, African-rice varieties from Guinea-Bissau proved higher yielding than those of other origin.

than the average Asian rice. Also, they often told us that it tastes "sweeter." And they said it keeps well after cooking. This is particularly important because many people prepare food only once a day, but members of the family drop by to eat at any time.

In northwestern Sierra Leone, however, Asian rice is preferred. People in this area complained that African rice is difficult to husk and that cleaning off its tough red bran takes a lot of work. Women in particular complained of the extra workload it imposes.

On the other hand, in other parts of the country redness was an important advantage. For example, Mende people in the south and east look on the red tinge (found on incompletely milled grains) as a guarantee that the sample is not a foreign rice. Rice soaked in palm oil plays a major part in their rituals, and it is unthinkable for them to use an Asian wetland variety.

In their fields, Sierra Leone farmers draw no distinction between Asian and African rices. Both species go by the same name: *mba* (Mende) or *pa* (Temne). The fields are very mixed from a genetic point of view. The farmers prefer it that way and, seemingly, they deliberately foster diversity because most of them know how to rogue out undesirable types and would do so if they wanted to.

We noticed that the African and Asian species appear to have hybridized in many places. A number of the most popular Temne rices, for example, are in fact intermediate types (judged by ligule form, grain shape, and panicle type). Certain named landraces seemed to be neither Asian nor African rice and may be assigned to either or both species.

Paul Richards, Serrie Kamara,
Osman Bah, Joseph Amara, Malcolm Jusu

LIMITATIONS

In its present state, African rice certainly has limitations, including those listed below:

- Lodging. The plants tend to have weak stalks, and late-season windstorms can sometimes topple them.
- Shattering. Today's plants tend to drop the seed as it matures.
- Splitting. The seed tends to break in half if handled roughly.
- Color. Although the grain itself is always white, most types have red husks.
- Processing. To remove the husk is laborious.

- Weediness. In West Africa, extensive genetic interaction occurs between African rice's wild and cultivated races. The mixed populations that build up can be extremely complex. The weedy results infest the rice fields and can be serious pests.[9]
- Diseases. Compared to Asian rice, it can be more susceptible to numerous fungi as well as to the parasitic plant striga and to a brown spot of unknown cause.

Although these limitations collectively add up to a fearsome combination, they mainly reflect the neglect this crop suffers from. All are now circumvented by people who grow and use African rice; research can undoubtedly reduce their severity if not overcome them entirely. Moreover, several of these limitations are also characteristic of competing grains.

NEXT STEPS

African rice must be kept from dying out as a crop. It deserves research, development, greater promotion, and support. At the very least it has genes of potential value to its near relation, the world's second biggest food crop. Actions to be taken include the following:

Friends of African Rice

A good start could be made by an organization of volunteers—both professionals and amateurs—who join together in a cooperative spirit to explore, protect, promote, and provide samples of this millennia-old resource. They might also collect the legends that come with the various types before they, too, die.

Information Exchange

Researchers are now working on rice in Senegal, Mali, Ghana, Ivory Coast, Burkina Faso, Cameroon, Liberia, Nigeria, Sierra Leone, and other countries. An international center, the West African Rice Development Association, specializes in the crop. And two French institutes, Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM) and Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières-Centre de Coopération Internationale en Recherche Agronomique pour le Développement (IRAT-CIRAD), also have rice programs in Africa. All but one of these organizations work almost exclusively on Asian rice, but the presence of their expertise means that there are good opportunities to advance the development of its African relative.[10] One way to stimulate

[9] Such a gene flow between wild and cultivated species is also of long-term benefit to the crop. It maintains a broad genetic base and enhances its ability to resist drought, pests, diseases, and other hazards. But to a farmer faced with the need for high yields of uniform grain, it can be a curse.

[10] Research contacts for these and other programs are listed in Appendix G.

interest within the international scientific community is to collect all available research data and publish a detailed monograph on African rice.

Food Processing

As noted earlier, the availability of precooked products made from African rice might do much to halt its decline and, indeed, to turn it around. Innovation, ingenuity, and marketing skill could be employed to return this food to prominence. It might well start out as a specialty product, selling at a premium to hotels for tourists and to those people dedicated to African traditions.

Seed Supply

In many areas the amount of seed in circulation is so low as to render the species nonviable. It is important to keep up a supply of seed. Then, at least, the farmers who want to keep growing African rice won't be excluded as is now apparently happening in Sierra Leone.

Germplasm

Samples of African rice have been gathered by various organizations, notably the International Plant Genetic Resources Institute (IPGRI), ORSTOM, and IRAT-CIRAD. This has been stored for purposes of conservation and possible plant breeding.[11]

For all that, however, many interesting types undoubtedly remain to be collected across the vastness of West Africa.

Agronomic Studies

Since little hard data on this crop exists, it would be useful for students of agronomy to take up the many challenges of "filling in the map." Examples include the following:

- Selecting nonshattering genotypes or developing techniques to overcome shattering.
- Testing strains for salt tolerance.
- Locating types for drought avoidance.
- Measuring cell sap osmotic adjustment.
- Testing the plant's storage capacity and dormancy requirements.
- Reducing broken grains. Certain strains of Asian rice also suffer this problem and recent research has shown that providing adequate nitrogen fertilizer largely overcomes it.[12]
- Research in deep-water rice is vital and long overdue. The resources available—climate, water, and growing area—along with

[11] A collection of about 4,000 samples of seeds of wild and cultivated African rice, as well as Asian rice landraces that have been cultivated in Africa for a long time, is held at ORSTOM and IRAT-CIRAD. It results from 14 collecting missions in 12 African countries. Eighty-five percent are cultivated landraces (both African and Asian); 15 percent are wild African species.

[12] This research was done by Robert H. Dilday, USDA-ARS Rice Production and Weed Control Research Unit, P.O. Box 287, Stuttgart, Arkansas 72160, USA.

proper research could perhaps triple production of deep-water rice in the Niger's inland delta. This is one area of research that can do something toward reducing hunger in one of the regions of Africa most in need of help.

Genetic Improvement

Although the current African types shed grain more readily than the Asian ones, some improvements have been bred into dryland varieties. Additional research emphasizing seed shattering could make a big difference. Because the gene for nonshattering is recessive, the selection of nonshattering types should be rapid, and true breeding should be immediate. Other improvements might include selection for resistance to disease. This resistance exists in the various genotypes, and the major problem is not to lose these local types as Asian rice spreads even further. For the uplands, any form of rice must resist blast and sheath blight. All types must also resist rice yellow-mottle virus; some local cultivars already do.

For areas dependent on seasonal flooding, varieties must resist lodging and respond to fertilizer; the transplant types must tolerate widely varying periods of growth in the nursery (while farmers await the onset of the unpredictable natural flooding).

Researchers are at present "mapping" the chromosomes of both African and Asian rice, identifying the portions that control various features of the plant.[13] This powerful modern technique will "jumpstart" the genetic improvement of African rice (see box, page 34). Perhaps it could also facilitate the transfer of useful genetic material between the two.

SPECIES INFORMATION

Botanical Name

Oryza glaberrima Steudel

Synonym

Oryza barthii ssp. *glaberrima*

Common Names

English: African rice, glaberrima rice
French: riz pluvial africain, vieux riz, riz africain, riz flottant
Cameroon: erisi (Banyong)
Guinea: Baga-malé, malé, riz des Baga
Mali: Issa-mo (river rice), mou-bér (great rice)
Sierra Leone: kebelei, mba, mbei (Mende), mala (Kissi), Kono, pa (Temne)

[13] Information from G. Second.

Description

African rice is an annual grass that grows generally between 66 and 120 cm tall. It is highly variable. The dryland types have smooth, simple culms that can form roots at the lower nodes and are simply branched up to the panicle (flower cluster). The floating types can form branches and even roots at the upper nodes. The panicles are stiff, smooth, and compact. The flowers are self-fertilizing; however, some inter- and intraspecific cross-pollination occurs.

From a distance, Asian rice and African rice are similar in appearance. However, African rice has diminutive ligules (small, thin membranes found at the base of the leaf where it joins the stem). Its compact panicles have less branching. Its spikelets lack lawns. It is completely annual and dies after setting seed. Asian rice, on the other hand, continues growing so that late in the season the two can look strikingly different.

Distribution

African rice is important mainly throughout the southwestern region of West Africa, but it can be found as far east as Lake Chad, especially in the lands of the Sahel that are seasonally flooded by the Niger, Volta, and other rivers.

It has apparently been introduced to India. Also, it may have been taken to Brazil by seventeenth-century Portuguese explorers. Somehow it has also reached El Salvador and Costa Rica.[14]

Cultivated Varieties

Many cultivars of African rice have been obtained by natural crossings and inbreeding, giving forms with compact panicles and heavy grains. In particular, there are numerous swamp varieties suited to different soil and drainage conditions.[15] In northern Mali alone are found about 30 cultivars of the floating type.[16] Examples of upland varieties of African rice are ITA 208, IRAT 112, Mutant 18, IRAT 104, and ISA 6.[17]

In Upper Gambia, Guinea, and Senegal (Casamance) can be found a special group of African-rice genotypes with enhanced recessive

[14] It was collected there in the 1950s by Roland Porteres, a French botanist who specialized in studying West African grasses and was a pioneer in bringing the promise of African rice to world attention.

[15] One researcher collected about 180 varieties in the inland Niger delta. P. Martin. 1976. Amélioration des conditions de production du riz flottant au Mali (période 19631-973). *L'Agronomie Tropicale* 31(2):194-201.

[16] Information from W. Schreurs.

[17] Information from J. Ayuk-Taken.

COULD AFRICAN RICE GO HIGH-TECH?

The world's rice research is overwhelmingly focused on Asian rice, but the remarkable developments now emerging from laboratories may bring big advances to African rice, on the side. Following are examples.

Gene Mapping. Molecular biologists have recently "marked" the locations on rice chromosomes where genes for certain genetic attributes are carried. These markers can be used to track the genes for those traits. The ability to determine whether a desired gene is present or absent in any sample bestows enormous power. It can, for instance, help find a desired gene in wild as well as cultivated species, it can find a "hidden" gene in a given plant where the gene's outward effects are masked, and it vastly simplifies the sorting of thousands of crossbred specimens—something that formerly could take a lifetime of tedious effort.

Gene markers based on restriction-fragment length polymorphisms (RFLPs) are being developed for both Asian and African rices. For instance, in 1988 a team at Cornell University found markers for various traits on the set of 12 chromosomes that (in both species) carries all the genetic characteristics. That first map had 135 genetic landmarks; later versions have more than 300.

A particular strength of this new work is that breeders can now work with very young seedlings. In other words, they can tell whether a certain gene is present without waiting months for the plant to mature. This can cut the time needed to breed a new variety—usually 10-12 seasons—in half.

Although the genomes (chromosome sets) of both African and Asian rice have been mapped, the rest of the effort has so far been solely on Asian rice. Nonetheless, most results from Asian rice are likely to be easily transferable. The genome is relatively small, containing only a tenth as much DNA as maize.

Test-Tube Reproduction. Although until recently no grass had been cloned using tissue culture, today Asian rice, maize, sorghum, and vetiver have succumbed. African rice has so far not been cultured in the test tube but, given the new insights, it seems a likely candidate for this powerful procedure.

Several teams have managed to regenerate fertile rice plants from protoplasts—cells from which the wall has been removed. This makes it even easier to fiddle with rice genes. Already, DNA from bacteria has been transferred into rice protoplasts. Mature plants, grown from these protoplasts, have transmitted the implanted DNA to their offspring.

High-Lysine Forms. In the early 1990s, U.S. Department of Agriculture researchers discovered Asian rice plants with both high protein quality and high protein levels. This has raised hopes that extremely nutritious varieties can be bred for the first time.

To find these new forms, Gideon W. Schaeffer, Francis T. Sharpe, Jr., and John Dudley gave small clumps of rice cells a lethal dose of lysine (an amino acid vital for good health) in a laboratory dish. Only a tiny fraction survived the treatment. Those few cells, however, could allow more lysine than normal to be made. The scientists grew them into whole rice plants and found that the resulting high-lysine plants are true genetic mutants and therefore suitable for breeding new commercial varieties. Some of the crossbreeds have succeeded in producing seed of near-normal weights and good fertility but with greatly enhanced nutritional quality.

The high-lysine trait is apparently controlled by a single recessive gene. The scientists have begun isolating this gene so as to provide it to genetic engineers for incorporation into the world's Asian-rice crop. The work would likely be easily transferable to create high-lysine forms of its African cousin.

Hybrids. Both the male and female parts on rice flowers are normally fertile, but researcher J. Neil Rutger of the U.S. Department of Agriculture has found that growing certain rice plants in 15-hour daylight makes them essentially female. The plants never develop fertile pollen. This may provide a cheap and easy way to boost rice yields to a much higher level than at present. Because the modified plants cannot pollinate themselves, they are ready-made for pollination by other plants. Any pollination, therefore, produces hybrids, which are often known to produce robust and high-yielding plants. This process has not yet been tested on African rice, but Rutger believes that it might well work.

Asaf Hybrids. Recent decades have seen several dozen research papers on the genetic and morphological results of crossing Asian rice with African rice. Most have emerged from laboratories in Japan, Taiwan, and China. The driving force behind them appears to be the attempt to raise the yield of Asian rice by forming hybrids.

At least in principle, crosses between African rice and Asian rice might improve the yield of either or both. Although the botanical literature stresses their incompatibility, the two are genetically close. Both are self-pollinating diploids (2n = 24) and possess the same genome, which rice geneticists call AA.

characters such as white husks, spikelets persisting to maturity, and vegetative and floral organs without anthocyanins. These seem to indicate a secondary region of diversity and may be particularly valuable genetic resources.

Environmental Requirements

Daylength

Varies from neutral to strongly sensitive, depending on variety. However, most dryland types now in use are sensitive to photoperiod. They flower with the advent of the dry season. On the other hand, most floating types (at least in northern Mali) show little sensitivity to daylength.

Rainfall

Some upland varieties can produce adequately with precipitation as low as about 700 mm.

Altitude

From sea level to 1,700 m.

Low Temperature

Average temperatures below about 25°C retard growth and reduce yields. Below about 20°C these effects are pronounced.

High Temperature

African rice does well at temperatures above 30°C. Above about 35°C, however, spikelet fertility drops off noticeably.

Soil Type

Some cultivars apparently can outperform Asian rice on alkaline sites as well as on phosphorus-deficient sites. Not unexpectedly, however, the crop performs best on alluvial soils.

Related Species

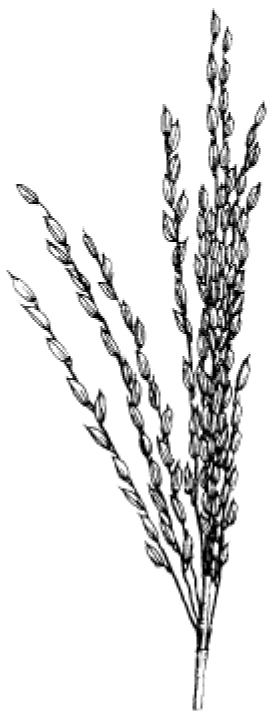
At least two of African rice's close relatives are regularly gathered for food, often in sufficient abundance to appear in the markets.

Orza barthii (*Oryza breviligulata*)[18] is an annual that commonly occurs in seasonally flooded areas from Mauritania to Tanzania and from the Sudan to Botswana. It is the wild progenitor of cultivated

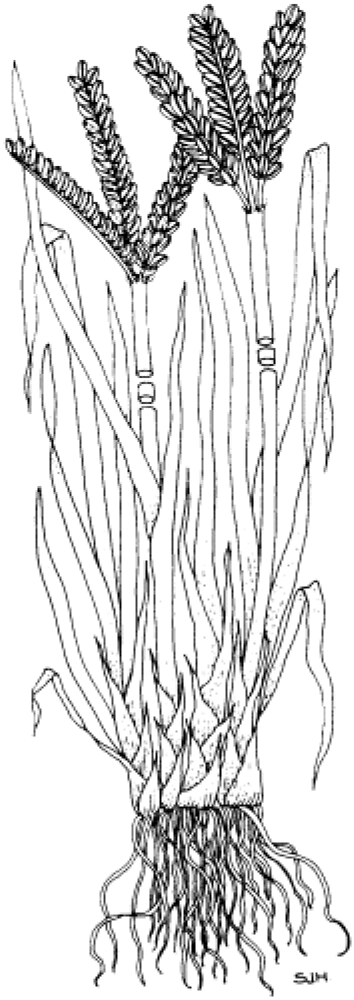
[18] The nomenclature of wild rices in Africa has been very confused. The names *Oryza stapfii, Oryza breviligulata,* and *Oryza barthii* often occur with uncertain usage. Much of the older literature is rendered useless by this. It is now considered that *Oryza barthii* is the direct ancestor of *Oryza glaberrima.* The name *Oryza breviligulata* is now considered invalid, as is *Oryza stapfii* the name formerly given to the weedy races of African rice.

African rice. It can form meadows in inundated areas. Its grain falls off so easily that it must be carefully collected by hand. (People use a basket or calabash, and sometimes they tie the stalks in knots to make harvesting easier.) It tastes good and is sometimes sold in markets. However, wherever rice is cultivated, this plant is regarded mostly as a weed to be eradicated. Certain strains of this species are immune to bacterial blight of rice (*Xanthomonas*), which could give them a valuable future as genetic resources.[19]

Oryza longistaminata is a common wild rice found throughout tropical Africa as far south as Namibia and Transvaal, as well as Madagascar. Unlike the other species, it is a perennial with rhizomes. It is tall and outcrossing. It usually grows in creeks and drainage canals and reproduces by suckers, often setting few seeds. Nonetheless, these meager grains are sought in times of shortage.



[19] S. Devadath. 1983. A strain of *Oryza barthii* an African wild rice immune to bacterial blight of rice. *Current Science* (Bangalore) 52(1): 27-28.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2

Finger Millet

Finger millet (*Eleusine coracana*) is hardly "lost." Indeed, it is one of the few special species that currently support the world's food supplies. This African native probably originated in the highlands of Uganda and Ethiopia, where farmers have been growing it for thousands of years. In parts of eastern and southern Africa as well as in India, it became a staple upon which millions depend. And its annual world production is at least 4.5 million tons of grain, of which Africa produces perhaps 2 million tons.

For all its importance, however, finger millet is grossly neglected both scientifically and internationally. Compared to the research lavished on wheat, rice, and maize, for instance, it receives almost none. Most of the world has never heard of it, and even many countries that grow it have left it to languish in the limbo of a "poor person's crop," a "famine food," or, even worse, a "birdseed."[1]

Further, in recent years this neglected crop has started an ominous slide that could propel it to oblivion even in Africa. In fact, it has declined so rapidly in southern Africa, Burundi, Rwanda, and Zaire, for instance, that some people predict that in a few years it will be hard to find—even where until recently it was the predominant cereal. In those areas it clings to existence only in plots that are grown for use on feast days and other occasions demanding prestige fare.

The world's attitude towards finger millet must be reversed. Of all major cereals, this crop is one of the most nutritious. Indeed, some varieties appear to have high levels of methionine, an amino acid lacking in the diets of hundreds of millions of the poor who live on starchy foods such as cassava and plantain. Outsiders have long marveled at how people in Uganda and southern Sudan could develop such strapping physiques and work as hard as they do on just one meal a day. Finger millet seems to be the main reason.

This crop has many other advantages as well. Its grain tastes better than most; Africans who know it usually prefer finger millet over all others. The plant is also productive and thrives in a variety of

[1] This is its main use in the United States, for example.

environments and conditions. Moreover, its seeds can be stored for years without insect damage, which makes them lifesavers for famine-prone areas.

Given all these qualities, it is perhaps hard to understand why finger millet is being rejected. But the reason is simple. People are giving it up in favor of maize, sorghum, and especially cassava because producing finger millet takes a lot of work.[2]

The truth is that finger millet, as produced at present, demands a dedication to drudgery that, given a choice, few people are willing to invest. Part of the terrible toil is in weeding the fields, part in handling the harvest, and part in processing the grain.

PROSPECTS

Even though finger millet is declining in the heartland where 30 years ago it was *the* major crop of the land, all is not lost. Indeed, if immediate attention is given, the impediments causing the decline will probably be eliminated. In fact, there are already signs that the slide may be bottoming out. Prices paid for finger millet have risen dramatically in some places, and the crop is enjoying something of a resurgence—and a highly profitable one at that. In Kenya, for instance, the grain currently sells at more than twice the price of sorghum and maize.[3] In Zimbabwe, too, the government offers an attractive producer price, which has tended to slow the decline. And Uganda's most recent statistics indicate that finger millet still occupies 50 percent of its cereal area.

Africa

If this crop is given proper attention, it has the following possibilities within Africa.

Humid Areas

Excellent prospects. Certain varieties are adapted to heat, humidity, and tropical conditions. (Finger millet was once the principal staple for people in southern Sudan and northern Uganda, for instance.) Given research, recognition, and sympathetic policies, production could expand dramatically.

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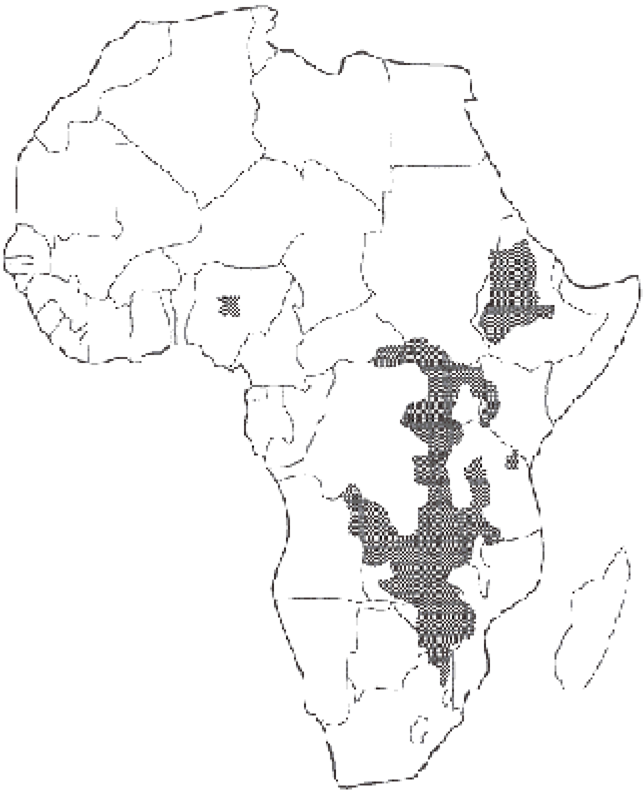
[2] At least one reviewer speculates that abandoning this nutritious grain millet for the less nutritious ones is "likely one of the causes of increasing famine in many areas."

[3] What is more, the government-controlled price (630 shillings per quintal, or \$0.29 per kilo in 1991) is only half the open-market price (1,200-1,400 shillings per quintal, or \$0.60 per kilo).

Finger millet seedheads look like "hands" with the grain contained in the "digits," hence the name. Some of the hands are curled into "fists." The crop is especially appreciated by the peoples in eastern and northern Uganda. To them, it has a high social value. They traditionally hold celebrations for the new harvest, and they serve finger millet bread to visitors and neighbors whom they want to impress. In the Uganda region, however, the people prefer finger millet in the form of hot porridge served with either sugar or banana juice.



Finger millet is grown throughout eastern and southern Africa, but especially in the subhumid uplands of Uganda, Kenya, Tanzania, Malawi, Zaire, Zambia, and Zimbabwe. The crop originated somewhere in the area that today is Uganda.

Dry Areas

Fair prospects. Finger millet is not as drought tolerant as pearl millet or even sorghum, but it could play a much greater role in savanna areas that get at least moderate rainfall.

Upland Areas

Excellent prospects. Certain finger millet landraces are fully adapted to highland conditions. In Africa the crop is usually grown at altitudes between 1,000 and 2,000 m and in Nepal it is grown at altitudes up to at least 2,400 m.

Other Regions

Finger millet is certainly not being abandoned in Asia. Indeed, India's national yields have increased 50 percent since 1955.[4] Moreover,

in Nepal, the finger millet area is expanding at the rate of 8 percent per year.[5] Any international efforts to promote and improve the plant appear to be as beneficial to Asia as to Africa.

This high-methionine grain might also be beneficial for use in weaning foods and in many other cereal products in parts of the world (Latin America and North America, for instance) where it is now largely ignored.

USES

This is a versatile grain that can probably be used in dozens of types of foods, including many that are quite unlike its traditional ones. Its several major uses include the following:

- Porridge. The small grains—which are usually brown but occasionally white—are commonly boiled into a thick porridge.
- Bread. Some finger millet is ground into flour and used for bread and various other baked products. All are relished for their flavor and aroma.
- Malt. Malted finger millet (the sprouted seeds) is produced as a food in a few places. It is nutritious, easily digested, and is recommended particularly for infants and the elderly.
- Beverages. Much finger millet in Africa is used to make beer. Its amylase enzymes readily convert starch to sugar. Indeed, finger millet has much more of this "saccharifying" power than does sorghum or maize; only barley, the world's premier beer grain, surpasses it. In Ethiopia, finger millet is also used to make *arake,* a powerful distilled liquor.
- Fodder. Finger millet straw makes good fodder—better than that from pearl millet, wheat, or sorghum. It contains up to 61 percent total digestible nutrients.
- Popped Products. Finger millet can be popped. It is widely enjoyed in this tasty form in India (see page 298).

[4] Most of the increase occurred between 1955 and 1975 and resulted from genetic improvement of India's traditional landraces. Subsequent increases were due to crosses between those and new strains introduced from Africa.

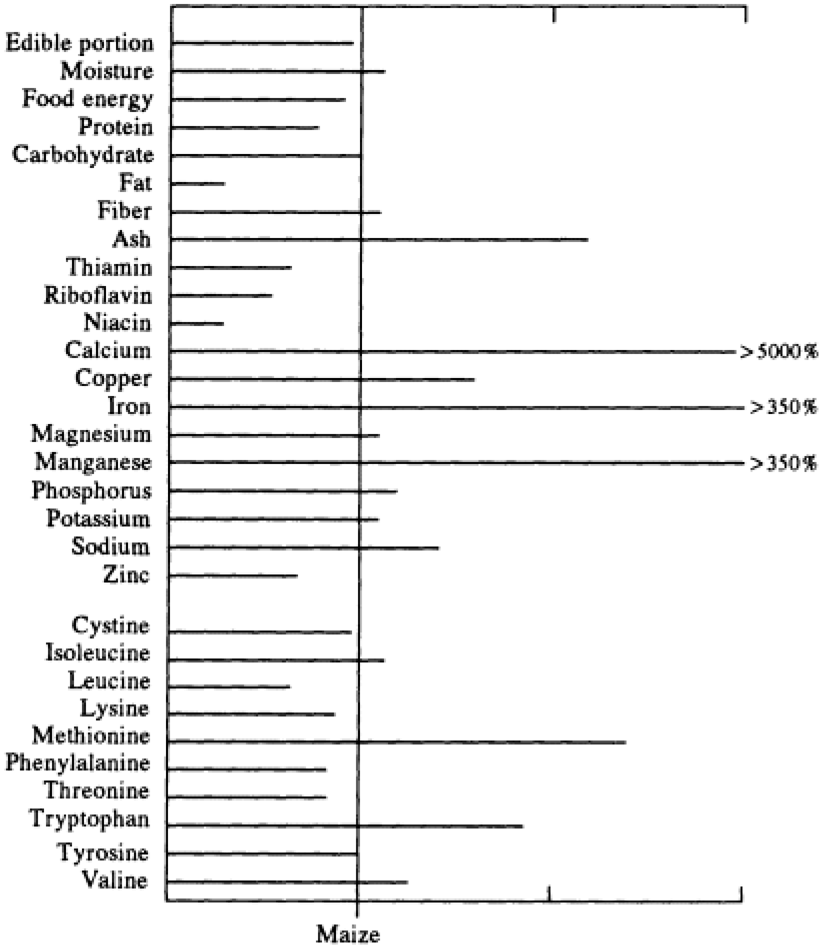
[5] In Nepal the crop has a special niche: during monsoon rains, it continues growing well, even when the soil is almost waterlogged and where the nutrients have been leached out by the daily downpours.

NUTRITIONAL PROMISE

Main Components		Essential Amino Acids	
Edible portion (g)	95	Cystine	1.7
Moisture (g)	12	Isoleucine	4.0
Food energy (Kc)	334	Leucine	7.8
Protein (g)	7.3	Lysine	2.5
Carbohydrates (g)	74	Methionine	5.0
Fats (g)	1.3	Phenylalanine	4.1
Fiber (g)	3.2	Threonine	3.1
Ash (g)	2.6	Tryptophan	1.3
Vitamin A (RE)	6	Tyrosine	4.1
Thiamin (mg)	0.24	Valine	6.4
Riboflavin (mg)	0.11		
Niacin (mg)	1.0		
Vitamin C (mg)	1		
Calcium (mg)	358		
Chloride (mg)	84		
Copper (mg)	0.5		
Iodine (µg)	10		
Iron (mg)	9.9		
Magnesium (mg)	140		
Manganese (mg)	1.9		
Molybdenum **(µg)**	2		
Phosphorus (mg)	250		
Potassium (mg)	314		
Sodium (mg)	49		
Zinc (mg)	1.5		

No single set of numbers can adequately convey the nutritional promise of a grain as variable as finger millet.The numbers in these pages should be taken withcaution. The dozen or someasurements that have been reportedgenerally agree on most ofthe different nutrients. However, proteincontents ranging from 6 to 14 percent have been claimed. The levels offat (1-1.4 percent) and foodenergy (323-350 Kc) that are normally givenare fairly consistentand are about the same as in maize. However,in some samples they seem to be much higher. The situation regardingiron is somewhat similar.Most analyses give the figure as about 5 mg per100 g. But there havebeen two reports of iron exceeding 17 mg.

COMPARATIVE QUALITY



Figures reported for the essential amino acids are generally consistent, but 3 percent methionine is commonly referred to in the literature. Possibly, this was based on degerminated flour. Even that figure is outstanding for a cereal grain.

In this chart, we have compared whole-grain finger millet with the standard figures for maize. These are perhaps not fair comparisons, but they do accurately reflect the differences between the forms in which each food is normally eaten.

NUTRITION

The grain's protein content (7.4 percent) is comparable to that of rice (7.5 percent). However, it shows considerable variation, and at least one Indian cultivar contains as much as 14 percent protein.

The main protein fraction (eleusinin) has high biological value, with good amounts of tryptophan, cystine, methionine, and total aromatic amino acids.[6] All of these are crucial to human health and growth and are deficient in most cereals. For this reason alone, finger millet is an important preventative against malnutrition. The methionine level—ranging around 5 percent of protein—is of special benefit, notably for those who depend on plant foods for their protein.

Finger millet is also a rich source of minerals. Some samples contain 0.33 percent calcium, 5-30 times more than in most cereals. The phosphorus and iron content can also be high.

AGRONOMY

In Asia, finger millet is planted in rows and managed much like other cereals. But in Africa it is usually handled differently. Unlike maize, sorghum, or pearl millet—all of which are planted at individual stands in a rough seedbed—finger millet is traditionally planted in Africa by broadcasting its tiny seeds. This demands a very fine seedbed and means that the farmers must work hard and long, both to prepare the land and to weed the young plants.

Two crops a year are possible with early-maturing types.

HARVESTING AND HANDLING

In most of Africa the crop is harvested by hand. Individual heads are cut off with a knife, leaving a few centimeters of stalk attached. These are piled in heaps for a few days, which fosters a fermentation whose heat and hydrolysis makes the seeds easier to thresh.

Finger millet seeds are so small that weevils cannot squeeze inside. In fact, its unthreshed heads resist storage pests so well they can be stored for 10 years or more without insect damage. (It is said that if kept dry the seed may remain in good condition for up to 50 years!)

Yields are variable but (compared to those of other grains in the area) are generally good. In Uganda, for example, a threshed yield of 1,800 kg per hectare is regarded as average. In India, on reasonable

[6] "Total aromatic acids" is the combination of phenylalanine and tyrosine.

dryland sites, yields may run to about 1,000 kg per hectare, and on irrigated sites a normal average is more than 2,000 kg per hectare. Yields of 5,000-6,000 kg per hectare have been obtained under ideal irrigated conditions. Similar yields have been obtained in Nepal even under rainfed conditions.[7]

LIMITATIONS

As has been noted, the small size of the seeds is a serious drawback. It makes the crop difficult to handle at all stages.

Weeding is a particular problem. In Africa the dominant weed, a wild relative of the crop, looks so much like finger millet in its early stages that only skilled observers and close scrutiny can tell them apart. The problem is compounded by the practice of broadcasting seed. To weed the resulting jumbled stands, people must inspect every plant, even going through on hands and knees.

Finger millet is subject to bird predators—notably to the notorious quelea (see Appendix A).

By and large, the plant suffers little from diseases and insects, but a ferocious fungal disease called "blast" can devastate whole fields.

Finger millet is almost entirely self-pollinating and crosses between different strains can be made only with difficulty. Until recently, genetic improvement was limited to pedigree-based selection. However, in Uganda a few plants with male sterility have now been discovered. These should ease the way to breeding methods in which different lines can be crossed without trouble.

Because the seeds are so small, it takes skill and much effort to convert finger millet into flour—particularly by hand. Even hammer mills have difficulty. They must be fitted with very fine screens and run at high speed. Recently, however, a special mill for millet has been devised (see next page).

NEXT STEPS

If finger millet is ever to be rescued, now is the time. The key is to find ways to present its plight and promise to the public and politicians and to develop its markets. A few motivated individuals could do much here. Among helpful actions might be a pan-African finger millet conference, where researchers and others could compare methods used to grow it, prepare it, and sell it in the various nations. This

[7] Information from K.W. Riley.

PROCESSING FINGER MILLET

Milling

Mechanical milling is of course well known; for wheat, rice, and maize, it is a major industry. But for finger millet, this primary step in the commercial processing of a food grain is essentially unknown. Machinery for rubbing the bran (embryo) off finger millet has never been available, perhaps through a lack of interest but mainly because the grain is exceptionally difficult to mill by machine. Finger millet, therefore, is usually eaten as a whole-grain flour, and the presence of oil in the embryo means that its shelf life is short and its commercial use limited.

Finger millet seed is a challenge to mill because it is very small and because its seed coat is bound tightly to the edible part (endosperm) inside. Moreover, the grain is so soft and friable that conventional milling equipment cannot remove the outside without crushing the inside. However, farmers have long known that moistening finger millet (for about 30 minutes) toughens the bran and reduces its grip enough that it can be mechanically separated without crushing the rest.

A machine for doing this has now been developed in India. This so-called "mini millet mill" consists of a water mixer, a plate grinder, and various sifter attachments. It is a versatile device in which debranning and sizing the endosperm (into either flour or semolina) take place in a single operation. It yields fairly white products. It can also be used to process wheat, maize, sorghum, and pearl millet and will even remove the outer husk from finger millet seeds if the clearance between the grinder plates is reduced.

This machine, and others like it, could initiate a new era for finger millet as a processed grain of commerce. The flour would then have a good shelf life and could be trucked to the cities and sold in stores as are wheat, rice, and maize. Commercial horizons would open up that have never before been contemplated.*

Malting

Finger millet could be the key to providing cheap and nutritious foods for solving, at last, the malnutrition that each year kills millions of babies throughout the warmer parts of the world.

As is described elsewhere (notably in appendixes C and D), the process of germinating finger millet activates enzymes that break down the complex structures of starches into sugars and other simple carbohydrates that are easy to digest. The enzymes

* For more information, contact N.G. Malleshi, Central Food Technological Research Institute (CFTRI), V.V. Mohalla PO, Mysore 570 013, India.

are of course there to benefit the seeds in which they occur—to mobilize food for the growing seedling; but long ago people found that they could use them also to break up starches from other sources. This process (usually called malting) became the first step in making beer and liquor out of starchy foods such as potatoes, maize, rice, or sorghum (see page 168).

What has been overlooked to a large extent is that malting can be used for more than just brewing. Indeed, it is probably the key to making cheap, digestible, liquid foods with little effort and no extra cooking fuel. These foods are particularly promising for children facing the life-threatening dietary switch from mother's milk to solid foods.

Adding a tiny amount of malted grain turns a bowl of hot starchy porridge into a watery liquid. The resulting food matches the viscosity of a bottled baby food, such as those sold in American supermarkets. A child who is too small or too weak to get down solids can then get a full meal—and get it out of the food its mother is preparing for the rest of the family.

The germinated grain acts as a catalyst to liquefy any of the world's major starchy foods: wheat, rice, maize, sorghum, millet, potatoes, cassava (manioc), yams, and the rest. Moreover, it does more than turn those staples into liquid form: it predigests the starches, making the food easy for a body to absorb, and (by releasing sugars) it renders even the blandest staples palatable. The malted grain is readily available, cheap, and safe to eat. It should develop healthy bodies and fully functioning brains in the millions of children whose health and happiness is now jeopardized by malnutrition.

Of all the world's cereal grains, finger millet is second only to barley in its ability to hydrolyze starches ("malting power"). And it has the inestimable value of growing in the latitudes where malnutrition is rife. (Barley is strictly a temperate-zone resource.)

But for all its potential to benefit the malnourished, not much attention has been paid to malting internationally. Only in India and Nepal have malt-based children's foods been intensively studied. In both countries, food scientists have created malted-grain products that can overcome malnutrition. And in almost every product, malted finger millet was the prime ingredient.

The fact that malting is a cheap and widely understood process that can be easily accomplished in the home or village and requires no fuel or special equipment is a major benefit. This means that top-quality weaning foods can be made by the poor, who cannot afford to buy commercial baby-food concoctions.

meeting would provide the opportunity to exchange experiences and to begin the process of preparing papers, pamphlets, recipes, and perhaps a monograph. Another might be the establishment of a "finger millet action program" to share seeds and research results in the future. There might even be established a pan-African finger millet "SWAT" team to provide advice and stimulus to the countries where finger millet is now declining toward economic extinction.

Rescuing this crop may be easier than now seems probable. Lifestyles and eating habits may have changed, but in much of Africa people still appreciate finger millet. Subsistence farmers like finger millet also. Every seed sown can return between 200 and 500 seeds (other grain crops seldom go above 100 even under ideal conditions). And this crop has many uses. To those whose very lives and livelihoods depend on what they grow, its flexibility is vital.[8]

Beyond Africa, finger millet should also be given a higher research priority. It is a good way to help the rural poor in parts of Asia. Much of the spectacular rise of wheat occurred in areas where irrigation could be used. Overcoming finger millet's yield constraints would, more importantly, benefit rainfed agriculture.

Research Needs

Research is needed on all aspects of this plant, which now is little known to scientists in general. ICRISAT is conducting research on it, but more effort is needed. Research operations might include those discussed below.

Trials in New Areas

Entrepreneurs in the United States as well as in Australia and other countries that specialize in cereal breeding could probably do much to benefit this crop. It is already grown in a small way in the United States. It grows well, but so far is used only for birdseed. Nonetheless, it might support a small specialty grain industry for local and national food uses. And enlisting the country's outstanding cereal-science capabilities could perhaps transform this crop's potential worldwide.

Farming Methods

As far as Africa is concerned, finger millet's greatest immediate needs lie not so much in plant breeding as in farming practices. Reducing the current drudgery involved with its production would bring the biggest and quickest benefits.

Surprisingly, techniques for making finger millet production less

[8] For crops like these, perhaps we need a whole new measure of performance, one that takes into account not just the yield in the field but the all-around value to people's welfare.

laborious can probably be employed rapidly and widely. For instance, planting the seed in rows would dramatically slash the need for weeding. One or two hoeings (or perhaps a layer of mulch) would eliminate most of the weeds with little further effort. To make this practical, however, a device is needed that can deliver small seed with precision. It would have to be easy to make and simple to use. Such devices do indeed exist (see Appendix A) but have not yet been introduced to finger millet farmers.

Examples of other types of farming practices worth exploring are the following:

- Minimum tillage seeding.
- Wide rows for water capture.
- Control of birds.
- Intercropping or undersowing with legumes. (The foliage from leguminous shrubs or ground cover may be especially helpful by supplying nitrogen to the crop.)
- Sowing or transplanting with other crops. (In Nepal, for instance, it is often planted with maize.)
- Weeding using animal power and other labor-saving techniques.
- Developing ox-drawn implements for planting, cultivating, harvesting, and threshing finger millet.

Erosion Control

In some parts of southern and eastern Africa finger millet has been abandoned because it "causes" severe soil erosion. In these areas, farmers typically clear forest from a hillside, burn it, and sow finger millet in the ashes. The tiny plants hold soil poorly, and it easily washes away. For such sites there is a need for alternative methods of erosion control. One example might be vetiver (see Appendix A). Another is mulching with stubble from the previous crop.

On the other hand, other parts of Africa actually employ finger millet for erosion control. In fact, when broadcast—or even line sown—across the slope it is good for reducing erosion. Data from Zambia, for example, show that the plant prevents erosion more effectively than legumes do. Farmers in Nepal also report that finger millet "holds the soil."

Plant Breeding

In its genetic development as a crop, finger millet is about where wheat was in the 1890s. Many landrace types are known but have not been systematically evaluated, codified, or analyzed, Thus it is likely that the best-yielding, best-tasting, and best-handling types have not been isolated or created out of the massive gene pool. Since the 1890s, average yields of wheat have risen from about 500 kg per

RAGI

Finger millet crossed the Indian Ocean more than 1,000 years ago and since then has become extremely important in South Asia. In India, where it is generally called "ragi," this native African grain is now grown on more than 2 million hectares.

In its new home, scientists and farmers have created numerous ragi races. There are, for instance, plants that are purple; seedheads that are short, long, "open," "curved," or "fisty"; seeds that range from almost black to orange-red; and there is also a popular type whose seeds are pure white. Some ragi varieties are dwarfs (less than 50 cm), some tiller profusely, some are slow to mature and are grown mainly under irrigation, while others mature quickly and lend themselves to dryland production.

Ragi is considered one of India's best dryland crops, and most of it is produced without supplemental water. The plant is both adaptable and resilient: it survives on lateritic soils, it withstands some salinity, and it has few serious diseases or pests. Ragi also yields well at elevations above those suitable for most other tropical cereals. In the Himalaya foothills, for example, it is cultivated up to slightly over 2,000 m above sea level.

Despite its importance in the Himalayas, about 75 percent of the ragi area lies in South India, particularly in Karnataka, Tamil Nadu, and Andhra Pradesh. In parts of this vast region farmers can get two crops a year; in Tamil Nadu and Andhra Pradesh three are not unknown. Wherever the rains at sowing time are uncertain, the farmers often transplant ragi like rice. In fact, the two crops are commonly grown in a "relay" that is good for both. For instance, in May a farmer may start out by sowing ragi seeds in the nursery; in June, he (or she) transplants the seedlings to the field and replants the nursery with rice seeds; in August, the ragi crop is harvested and the rice seedlings are put out into the just vacated fields. This process is efficient, highly productive, and a good insurance against the vagaries of the weather.

Ragi yields as much as 5,000 kg of grain per hectare. Because the seed can be stored for decades (some say 50 years), it is highly valued as a reserve against famines.

However, ragi is much more than just a famine food. In certain regions it is an everyday staple. It is, for instance, a principal cereal of the farming classes in Karnataka, Tamil Nadu, and Andhra Pradesh, as well as in the Himalaya hill tracts (including those of Nepal). The grain is mainly processed into flour, from which is made a variety of cakes, puddings, porridges, and other

Indian farmer holding ragi (ICRISAT).

tasty foods. Some, however, is malted and turned into beer as well as into easily digested foods for infants and invalids.

As in its African homeland, ragi enjoys a reputation for being both nutritious and sustaining, and Indian studies lend scientific support to this view. Certain grain types, particularly the white ones, can match the most nutritious local cereals, at least in protein content.

hectare to more than 4,000 kg per hectare; finger millet's could rise similarly and much more quickly.

Various finger millet landraces possess genes for blast resistance, robust growth, early vigor, large panicle size, high finger number and branching, and high-density grain. Similarly, there are water-efficient types with high carbon dioxide fixation and low leaf area that could be outstanding new crops for semiarid conditions. Long-glume types with high seed weight are especially promising for increasing seed size. All of these, and more, are genetic raw materials that could transform this crop.

The grain is already nutritious, but it might be improved even more. As noted, types containing up to 14 percent protein are known. Also, it is a high-methionine protein and, of all the essential amino acids, is the most difficult to find in grain-based foods. Thus these finger millets could be a "super cereal" in nutritional terms.

White-seeded forms that make good unleavened bread and bakery products are also known, and they too are undeveloped. Today's crop in Africa is overwhelmingly the coarse, rusty-red form that is mainly useful for porridge and brewing beer.

Hybrids between Indian and African varieties seem promising as well. These high-yielding "Indaf" types are popular in India. Similar hybridization and selection for improved Indaf varieties for African conditions is now being started.[9] Hybridization, however, is difficult and mutation breeding is another approach worth exploring.

Some of finger millet's relatives have interesting traits that might be transferable. Among wild *Eleusine* species are perennials that might lend some of their enduring characteristics to finger millet. Others have genes for tolerance of heat, cold, drought, and waterlogging, as well as resistance to salinity and an ability to mobilize phosphorus and utilize nitrogen efficiently.[10]

Less dramatic but more immediately practical plant-breeding needs are the fine-tuning of today's varieties. The most important objectives are resistance to blast,[11] helminthosporium (another fungus), striga (parasitic witchweed), lodging, stressful soil and moisture conditions, and grain that can be more easily dehulled and ground. Other objectives might include fast seedling growth to compete better with weeds, shade-tolerant types for relay and intercropping, and types with anthocyanin pigmentation in the leaves (possibly obtainable through

[9] This work is beginning at the SADCC/ICRISAT Center at Bulawayo, Zimbabwe (see Research Contacts).

[10] These wild relatives are currently being collected by IPGRI, but several that could be part of the primary or secondary gene pool are not yet represented by even a single collection.

[11] Recently, a number of blast-resistant types have been selected at ICRISAT and are undergoing yield tests in different sites.

induced mutation), which could be spotted easily in the fields and would make weeding a much easier task.[12]

Post Production Research

Reducing the labor to dehull and to grind grain is obviously a vital need. Less urgent needs include: (1) improvement of malting quality (important both for brewing and for making high-methionine weaning foods); and (2) new methods of processing, such as parboiling, milling, and puffing (see Appendix B).

SPECIES INFORMATION

Botanical Name

Eleusine coracana (L.) Gaertner

Common Names

Afikaans (and Dutch): vogel gierst
Arabic: tailabon
Bantu: bule
English: finger millet, African millet; koracan
French: petit mil, eleusine cultivée, coracan, koracan
German: Fingerhirse
Swahili: wimbi, ulezi
Ethiopia: dagussa (Amharic/Sodo), tokuso (Amharic), barankiya (Oromo)
India: ragi
Kenya: wimbi (kiswahili), mugimbi (Kikuyu)
Malawi: mawere, lipoko, usanje, khakwe, mulimbi, lupodo, malesi, mawe
Nepal: koddo
The Sudan: tailabon (Arabic), ceyut (Bari)
Tanzania: mwimbi, mbege
Uganda: bulo
Zambia: kambale, lupoko, mawele, majolothi, amale, bule
Zimbabwe: rapoko, zviyo, njera, rukweza, mazhovole, uphoko, poho

Description

Finger millet is a tufted annual growing 40-130 cm tall, taking between 2.5 and 6 months to mature. It has narrow, grass like leaves and many tillers and branches. The head consists of a group of digitately arranged spikes.

It is a tetraploid.

[12] Information from A. Shakoor.

Distribution

Finger millet derives from the wild diploid *Eleusine africana.*[13] There is archaeological evidence that before maize was introduced it was a staple crop of the southern Africa region. Today it is found throughout eastern and southern Africa and is the principal cereal grain in Uganda, where it is planted on more than 0.4 million hectares (especially in northern and western regions), as well as in northeastern Zambia. It is also an important backup "famine food" as far south as Mozambique.

Finger millet does not appear to have been adopted in ancient Egypt, and it is said to have reached Europe only about the beginning of the Christian era. However, it arrived in India much earlier, probably more than 3,000 years ago, and now it is an important staple food in some places, particularly in the hill country in the north and the south.

Cultivated Varieties

Numerous cultivars have been recognized in India and Africa, consisting of highland and lowland forms, dryland and irrigation types, grain and beer types, and early- and late-maturing cultivars. By and large, there are highland races and lowland races—each adapted to its own climate.

Environmental Requirements

Daylength

Finger millet is a short-day plant, a 12-hour photoperiod being optimum for the best-known types. It has been successfully grown in the United States as far north as Davis, California (with considerable problems of photoperiod sensitivity), and it is widely grown in the Himalayas (30°N latitude); however, it is mainly produced within 20°N and 20°S latitude. Daylength-neutral types probably exist.

Rainfall

It requires a moderate rainfall (500-1,000 mm), well distributed during the growing season with an absence of prolonged droughts. Dry weather is required for drying the grain at harvest. In drier areas with unreliable rainfall, sorghum and pearl millet are better suited. In wetter climates, rice or maize is preferable.

Altitude

Most of the world's finger millet is grown at intermediate elevations, between 500 and 2,400 m. Its actual altitude limits are unknown.

Low Temperature

The crop tolerates a cooler climate than other millets. For an African native, this crop is surprisingly well adapted to the temperate zones.

[13] This wild ancestor has at least one genome derived from *Eleusine indica* (Hilu, 1988).

High Temperature

Finger millet thrives under hot conditions. It can grow where temperatures are as high as 35°C.[14] In Uganda, the crop grows best where the average maximum temperature exceeds 27°C and the average minimum does not fall below 18°C.[15]

Soil Type

The crop is grown on a variety of soils. It is frequently produced on reddish-brown lateritic soils with good drainage but reasonable water-holding capacity. It can tolerate some waterlogging.[16] It seems to have more ability to utilize rock phosphate than other cereals do.[17]

[14] Information from J.A. Ayuk-Takem.
[15] Thomas, 1970.
[16] In recent trials of nine cereal species subjected to waterlogging from seedling to heading, finger millet was the most resistant, except for rice. It resisted waterlogging much better than maize. (Kono et al., 1988.)
[17] In pot experiments, the rock phosphate mobilizing capacity increased in the order maize: pearl millet: finger millet. (Flack et al., 1987.)

3

Fonio (Acha)

Fonio (*Digitaria exilis* and *Digitaria iburua*) is probably the oldest African cereal. For thousands of years West Africans have cultivated it across the dry savannas. Indeed, it was once their major food. Even though few other people have ever heard of it, this crop still remains important in areas scattered from Cape Verde to Lake Chad. In certain regions of Mali, Burkina Faso, Guinea, and Nigeria, for instance, it is either *the* staple or a major part of the diet. Each year West African farmers devote approximately 300,000 hectares to cultivating fonio, and the crop supplies food to 3-4 million people.

Despite its ancient heritage and widespread importance, knowledge of fonio's evolution, origin, distribution, and genetic diversity remains scant even within West Africa itself. The crop has received but a fraction of the attention accorded to sorghum, pearl millet, and maize, and a mere trifle considering its importance in the rural economy and its potential for increasing the food supply. (In fact, despite its value to millions only 19 brief scientific articles have been published on fonio over the past 20 years.)

Part of the reason for this neglect is that the plant has been misunderstood by scientists and other decision makers. In English, it has usually been referred to as "hungry rice," a misleading term originated by Europeans who knew little of the crop or the lives of those who used it.[1] Unbeknownst to these outsiders, the locals were harvesting fonio not because they were hungry, but because they liked the taste. Indeed, they considered the grain exotic, and in some places they reserved it particularly for chiefs, royalty, and special occasions. It also formed part of the traditional bride price. Moreover, it is still held in such esteem that some communities continue to use it in ancestor worship.[2]

Not only does this crop deserve much greater recognition, it could have a big future. It is one of the world's best-tasting cereals. In recent

[1] Information from J. Harlan. In Nigeria it is usually called "acha."

[2] It is important this way to the Dogon, a people of Mali. To them, the whole universe emerged from a fonio seed—the smallest object in the Dogon experience—a sort of atomic cosmology. (Information from J. Harlan.)

times, some people have made side-by-side comparisons of dishes made with fonio and common rice and have greatly preferred the fonio.

Fonio is also one of the most nutritious of all grains. Its seed is rich in methionine and cystine, amino acids vital to human health and deficient in today's major cereals: wheat, rice, maize, sorghum, barley, and rye. This combination of nutrition and taste could be of outstanding future importance. Most valuable of all, however, is fonio's potential for reducing human misery during "hungry times."

Certain fonio varieties mature so quickly that they are ready to harvest long before all other grains. For a few critical months of most years these become a "grain of life." They are perhaps the world's fastest maturing cereal, producing grain just 6 or 8 weeks after they are planted. Without these special fonio types, the annual hungry season would be much more severe for West Africa. They provide food early in the growing season, when the main crops are still too immature to harvest and the previous year's production has been eaten.

Other fonio varieties mature more slowly—typically in 165-180 days. By planting a range of quick and slow types farmers can have grain available almost continually. They can also increase their chances of getting enough food to live on under even the most changeable and unreliable growing conditions.

Of the two species, white fonio (*Digitaria exilis*) is the most widely used. It can be found in farmers' fields from Senegal to Chad. It is grown particularly on the upland plateau of central Nigeria (where it is generally known as "acha") as well as in neighboring regions.

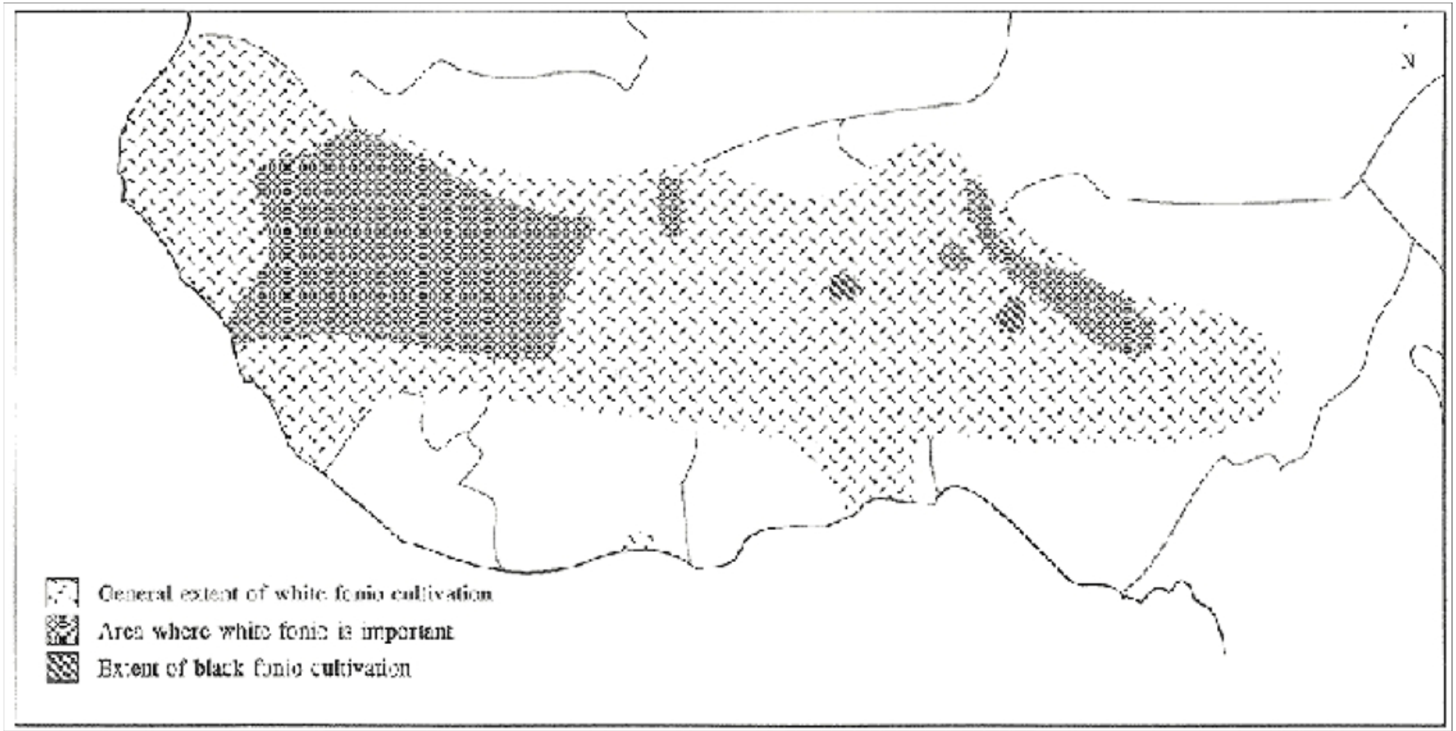
The other species, black fonio (*Digitaria iburua*), is restricted to the Jos-Bauchi Plateau of Nigeria as well as to northern regions of Togo and Benin.[3] Its restricted distribution should not be taken as a measure of relative inferiority: black fonio may eventually have as much or even greater potential than its now better-known relative.

PROSPECTS

Unlike finger millet, African rice, sorghum, and other native grains, fonio is not in serious decline. Indeed, it is well positioned for improved production. First, it is still widely cultivated and is well known. Second, it is highly esteemed. (In Nigeria's Plateau State, for example, the present 20,000-ton production is only a quarter of the projected state demand.[4]) Third, it tolerates remarkably poor soil and will grow

[3] Both have white seeds but black fonio has black or dark brown spikelets.
[4] T. Mabbett. 1991. *African Farming* Jan/Feb:25-26.

Fonio has a lacy appearance. It is often less than knee high. (Nazmul Haq)



For a crop that is so little known to science, fonio is surprisingly widely grown. It is employed across a huge sweep of West Africa, from the Atlantic coast almost to the boundary with Central Africa.

where little else succeeds. These are good underpinnings for fonio's future advancement.

Africa

Humid Areas

Low prospects. Fonio is mainly a plant of the savannas and is probably ill adapted to lowland humid zones. It seems likely to succumb to various fungal and bacterial diseases. However, white fonio does grow around the Gola Forest in southeastern Sierra Leone, and black fonio is reportedly cultivated in Zaire and some other equatorial locations. These special varieties (occasionally misnamed as *Digitaria nigeria*) are possibly adapted to hot and humid conditions.

Dry Areas

High prospects. People in many dry areas of West Africa like fonio. They know that it originated locally, and they have long-established traditions for cultivating, storing, processing, and preserving it. During thousands of years of selection and use, they have located types well adapted to their needs and conditions. Although the plant is not as drought resistant as pearl millet, the fast-maturing types are highly suited to areas where rains are brief and unreliable.

Upland Areas

Excellent prospects. Fonio is the staple of many people in the Plateau State of Nigeria and the Fouta Djallon plateau of Guinea, both areas with altitudes of about 1,000 m.

Other Regions

This plant should not be moved out of its native zones. In more equable parts of the world it might become a serious weed.[5]

USES

Fonio grain is used in a variety of ways. For instance, it is made into porridge and couscous, ground and mixed with other flours to make breads, popped,[6] and brewed for beer. It has been described as

[5] It is a relative of crabgrass, a European crop introduced to the United States in the 1800s as a possible food and now a much-reviled invader of lawns. However, white fonio is grown for forage in parts of the United States—apparently without causing problems.

[6] Little or nothing has been reported on popping this crop, but in southern Togo women put a little fonio into a metal pot and swirl it over a fire. Within a few seconds the grains begin bursting and bouncing, and the result is a light and puffy white material. Information from D. Osborn.

a good substitute for semolina—the wheat product used to make spaghetti and other pastas.

In the Hausa region of Nigeria and Benin, people prepare a couscous (*wusu-wusu*) out of both types of fonio. In northern Togo, the Lambas brew a famous beer (*tchapalo*) from white fonio. In southern Togo, the Akposso and Akebou peoples prepare fonio with beans in a dish that is reserved for special occasions.

Fonio grain is digested efficiently by cattle, sheep, goats, donkeys, and other ruminant livestock. It is a valuable feed for monogastric animals, notably pigs and poultry, because of its high methionine content.[7] The straw and chaff are also fed to animals. Both make excellent fodder and are often sold in markets for this purpose. Indeed, the crop is sometimes grown solely for hay.

The straw is commonly chopped and mixed with clay for building houses or walls. It is also burned to provide heat for cooking or ash for potash.

NUTRITION

In gross nutritional composition, fonio differs little from wheat. In one white fonio sample, the husked grain contained 8 percent protein and I percent fat.[8] In a sample of black fonio, a protein content of 11.8 percent was recorded.[9]

The difference lies in the amino acids it contains. In the white fonio analysis, for example, the protein contained 7.3 percent methionine plus cystine. The amino acid profile compared to that of whole-egg protein showed that except for the low score of 46 percent for lysine, the other scores were high: 72 for isoleucine; 90-100 for valine, tryptophan, threonine, and phenylalanine; 127 for leucine; 175 for total sulfur; and 189 percent for methionine.[10]

This last figure means that fonio protein contains almost twice as much methionine as egg protein contains. Thus, fonio has important potential not only as survival food, but as a complement for standard diets.

AGRONOMY

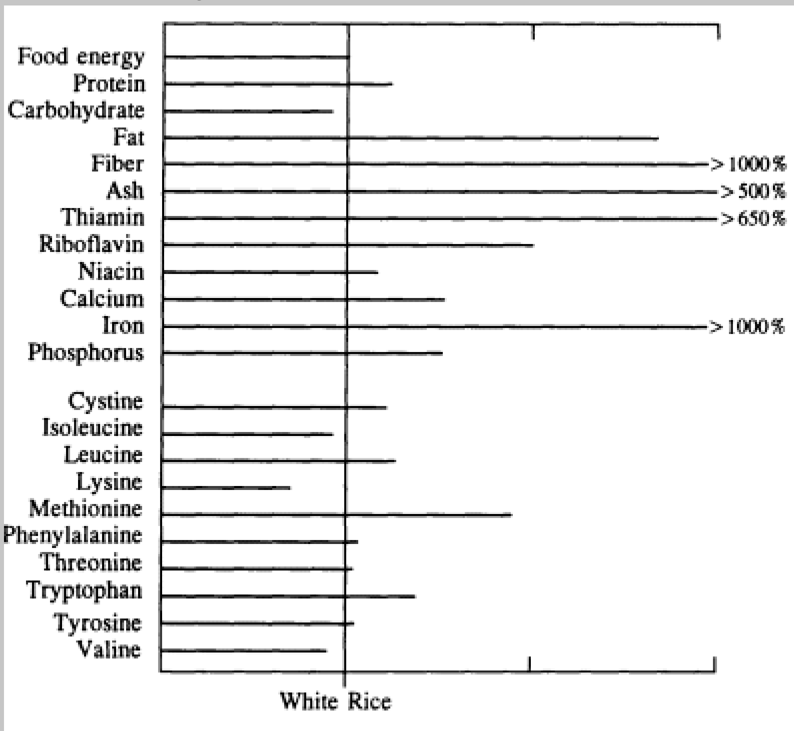
Fonio is usually grown on poor, sandy, or ironstone soils that are considered too infertile for pearl millet, sorghum, or other cereals. In

[7] Göhl, 1981.
[8] De Lumen et al., 1986.
[9] Carbiener et al., 1960.
[10] Using the FAO, A/E approach. Information from B. Standal. One analysis has reported a methionine level as high as 5.6 percent.

NUTRITIONAL PROMISE

Main Components		Essential Amino Acids	
Moisture	10	Cystine	2.5
Food energy (Kc)	367	Isoleucine	4.0
Protein (g)	9.0	Leucine	10.5
Carbohydrate (g)	75	Lysine	2.5
Fat (g)	1.8	Methionine	4.5
Fiber (g)	3.3	Phenylalanine	5.7
Ash (g)	3.4	Threonine	3.7
Thiamin (mg)	0.47	Tryptophan	1.6
Riboflavin (mg)	0.10	Tyrosine	3.5
Niacin (mg)	1.9	Valine	5.5
Calcium (mg)	44		
Iron (mg)	8.5		
Phosphorus (mg)	177		

COMPARATIVE QUALITY



Fonio is an extremely adaptable plant that is little affected by climatic or soil conditions, Much of it is found growing in semiarid areas. In the Fouta Djallon Plateau of Guinea (shown here), it grows on acidic soils with high aluminum content that are deadly to other crops. (Nazmul Haq)

Guinea's Fouta Djallon region, where fonio is common, the soils are acidic clays with high aluminum content—a combination toxic to most food crops. It is generally grown just like upland rice, and the two are frequently produced by the same farmers. Normally, the seed is broadcast and covered by a light hoeing. It germinates in 3-4 days and grows very rapidly. This quick establishment and the heavy seeding rate (usually 10-20 kg of seed per hectare) ensures that the fields seldom need weeding. In a few cases the crop is transplanted from seedbeds to give it an even better chance at surviving the harsh conditions.

In Sierra Leone, and probably elsewhere, fonio is often grown following, or even instead of, wetland rice. This is done particularly when the season proves too dry for good paddy production and the farmers decide to give up on the rice. Fonio thus serves as an insurance against total crop failure.

In certain areas, fonio may sometimes be planted together with sorghum or pearl millet. Indeed, it is frequently the staple, while the other two are considered reserves. Commonly, farmers in Guinea sow multiple varieties of fonio and then later fill in any gaps with fast maturing varieties of guinea millet (*Brachiaria deflexar*).[11]

HARVESTING AND HANDLING

Fonio grain is handled in traditional ways. The plants are usually cut with a knife or sickle, tied into sheaves, dried, and stored under cover. Good yields are normally 600-800 kg per hectare, but more than 1,000 kg per hectare has been recorded. In marginal areas, yields may drop to below 500 kg and on extremely poor soils may be merely 150-200 kg per hectare.[12]

Traditionally, the grain is threshed by beating or trampling, and it is dehulled in a mortar. This is difficult and time-consuming.

The seed stores well.

LIMITATIONS

Because of the lack of attention, fonio is still agronomically primitive. It suffers from small seeds, low yields, and some seed shattering.

The plant responds to fertilizers, but most types are so spindly that fertilization makes them top-heavy and they may blow over (lodge).

[11] Portères, 1976. This fonio-like grain is described in the chapter on other cultivated grains, page 237.

[12] As noted elsewhere, yield figures such as these can be very misleading. They may be low, but hungry rice produces a yield on sites or in seasons when other cereals yield nothing whatever.

FONIO: IT'S NOT JUST A FAMINE FOOD

Late in 1990, I interviewed a farmer with a largish plot of fonio. It was just a few kilometers from Bo town, in central Sierra Leone. What especially intrigued me was that this was not, as I at first supposed, a poverty-stricken woman's attempt to grow a little food for household subsistence. It was instead a commercial venture, aimed at the Bo market. There, fonio sells (cup for cup) at a better price than rice. By selling her crop she would be able to buy a larger amount of rice. To me, this was a striking confirmation of the commercial potential of this almost entirely neglected crop. To the people who know it, fonio is treasured more highly than rice!

Paul Richards

Birds may badly damage the crop in some areas; bird-scaring is usually necessary in those locations. The plants are also susceptible to smut and other fungal diseases.

It has been reported that fonio causes soil deterioration, but this appears to be a misperception. It is often sown on worn-out soils, sometimes even after cassava (the ultimate crop for degraded lands elsewhere). It is this association with poor soils that has given rise to the rumor, but the soils were in fact impoverished long before the fonio was put in.

Some groups dislike black fonio because, compared with the white form, it is more difficult to dehusk with the traditional pestle.

The seed loses its viability after two years.

Because of its small seed size, the harvest is very difficult to winnow. Sand tends to remain with the seed and produces gritty foods. It is therefore necessary to thresh fonio on a hard surface rather than on bare ground. Also, just before cooking, the grains are usually washed to rid them of any remaining sand.

NEXT STEPS

Clearly, fonio is important, has many agronomic and nutritional virtues, and could have an impressive future. This crop deserves much greater attention. Modern knowledge of cereal-crop improvement and dedicated investigations are likely (at modest cost) to make large advances and improvements. Yields can almost certainly be raised

dramatically, farming methods made less laborious, and markets developed—all without affecting the plant's resilience and reliability. These results, and more, are likely to come about quickly once fonio becomes as important to the world's scientists as it is to West Africa's farmers.

Promotion

General activities to raise awareness of this crop's value and potential include a monograph, a newsletter, a "friends of fonio" society, a fonio cookbook, a series of fonio cook-offs, and fonio conferences. These could be complemented by publicity, seed distributions, and experiments to test fonio's farm qualities and cultivation limits.

It should not be too difficult to generate excitement for this "lost gourmet food of the great ancestors." It might prove a good basis for recreating traditional cuisines. Even export as a highly nutritious specialty grain is a possibility.

Scientific Underpinnings

Despite its importance, fonio is a crop less than halfway to its potential. There have been few, if any, attempts to optimize, on a scientific basis, the process of growing it. Its taxonomy, cultivation, nutritional value, and time to harvest are only partially documented. Varieties have neither been compared, nor their seed even collected, on a systematic basis. Little or no research has been done on postharvest deterioration, storage, or preservation methods.

Germplasm Collection

An early priority should be to collect germplasm.[13] Varieties are particularly numerous in the Fouta Djallon Plateau in Guinea and around the upper basins of the Senegal and Niger Rivers.[14] Among these will certainly be found some outstanding types. This alone seems likely to lead to better cultivars that will bring marked advances in fonio production. The collection should also be screened to determine if yield is limited by viruses.[15] If so, the creation of virus-free seed might also boost yields dramatically.

Seed Size

The smallness of the grain offers a special challenge to cereal scientists: can the seeds be enlarged—perhaps through selection, hybridization, or other genetic manipulation?

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[13] One reviewer suggested asking village schoolmasters to collect seeds of all the different types in their areas. He reports getting outstanding assistance in this way on a project (in northern Nigeria) dealing with another widespread but little-known crop.

[14] Historically, these were the domains of the old empires of Mali, developed in the twelfth and thirteenth centuries, and it is there that fonio probably was brought to its apogee.

[15] In 1985, pangola grass (*Digitaria decumbens*), a related species that is widely planted as a tropical forage, was found to carry a stunt virus.

Yield

The cause of the low yields needs investigation. Is it because of the sites, diseases and pests, poor plant architecture, inefficient root structure, lodging, poor tillering, bolting, or daylength restrictions? What are optimum conditions for maximum yields? Can fonio's productivity approach that of the better-known cereals'?

Grain Quality

Cereal chemists should analyze the grains. What kinds of proteins are present? What are the amino-acid profiles of the different proteins? Nutritionists should evaluate the biological effectiveness of both the grains and the products made from them. There are probably happy surprises waiting to be discovered. In particular, protein fractionation is likely to turn up fractions with methionine and cystine levels even greater than fonio's already amazingly high average.

The exceptional content of sulfur amino acids (methionine plus cystine) should make fonio an excellent complement to legumes. Feeding studies to verify this are in order. The combination could be nutritionally outstanding.

Cytogenetics

As a challenge to geneticists, fonio has a special fascination. It has no obvious wild ancestor. That it appears to be a hexaploid (2n=6x=54) may help account for this. Does it, in fact, contain three diploid genomes of different origin? What are its likely ancestors, and might they be used to increase its seed size and yield?

Plant Architecture

Lodging is a serious drawback, especially when the soil is fertile. This may be overcome by dwarfing the plant or endowing stronger stems by plant breeding. How "free-tillering" are the various types?

Other Uses

Certain other *Digitaria* species are cultivated exclusively as fodder, whereas some are notable for their soil-binding properties and ability to produce an excellent turf. Is fonio also useful for such purposes? Could it, too, become a valuable all-purpose plant for many regions? Could improved fonio be "naturalized" in the northern Sahel to increase the availability of wild grain to nomadic groups?

Sociocultural Factors

How is the crop currently cultivated, distributed, and processed? What roles are played by social and cultural

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Fonio is characterized by the very small size of its seeds. The tiny white grains have many uses in cooking: porridge, gruel, and couscous, for example. They are also the prime ingredient in several choice dishes for religious and traditional ceremonies. (Brent Simpson)

factors such as the division of labor, traditional beliefs, and people's expectations? (Fonio, after all, is seldom if ever grown under optimum conditions.) Its promotion will succeed best in West Africa if its development is placed within such local constraints.

Processing

The processing and cooking of this crop is extremely arduous. Unless this can be relieved, fonio will probably never reach its potential.

SPECIES INFORMATION

Botanical Names

Digitaria exilis Stapf and *Digitaria iburua* Stapf[16]

Synonyms

Paspalum exile Kippist; *Panicum exile* (Kippist) A. Chev.; *Syntherisma exilis* (Kippist) Newbold; *Syntherisma iburua* (Stapf) Newbold (for *Digitaria iburua*)

Common Names

English: hungry rice, hungry millet, hungry koos, fonio, fundi millet
French: fonio, petit mil (a name also used for other crops)
Fulani: serémé, foinye, fonyo, fundenyo
Bambara: fini
Nigeria: acha (*Digitaria exilis,* Hausa); iburu (*Digitaria iburua,* Hausa); aburo
Senegal: eboniaye, efoleb, findi, fundi
The Gambia: findo (Mandinka)
Togo: (*Digitaria iburua*)*;* afio-warun (Lamba); ipoga (Somba, Sampkarba); fonio ga (black fonio); ova (Akposso)
Mali: fani, feni, foundé
Burkina Faso: foni
Guinea: pende, kpendo, founié, pounié
Benin: podgi
Ivory Coast: pom, pohin

Description

As noted, there are actually two species of fonio. Both are erect, free-tillering annuals. White fonio (*Digitaria exilis*) is usually 30-75 cm tall. Its finger-shaped panicle has 2-5 slender racemes up to 15 cm

[16] Black fonio has been known to science only since 1911, when a botanist recognized that what was growing in fields with pearl millet in the Zaria region of northern Nigeria was a species new to science.

FONIO AS FAST FOOD

As noted elsewhere (especially in Appendix C), a lack of processed products is holding back Africa's native grains. One grass-roots organization is doing something about this: it is turning fonio into a convenience food.

In southern Mali, fonio is mainly grown by women on their individual plots. Perhaps not unexpectedly, then, it is a women's group that has chosen to foster the grain's greater use. The group aims to raise fonio consumption by producing a precooked flour.

The project, backed by the Malian Association for the Promotion of the Young (AMPJ), is staffed and run entirely by women. Their goal is a fast-cooking fonio that will challenge parboiled rice and pre-packaged pasta (both of which are usually imported) in the Bamako markets.

The new "instant" fonio comes in 1-kg plastic bags and is ready for use. It requires no pounding or cleaning. It can be used to prepare all of the traditional fonio dishes. It is simple to store and handle. It is clean and free of hulls and dirt. And it requires less than 15 minutes to cook. For the user, then, it offers an enormous saving in both effort and time.

The project is currently a small one, designed to handle 6 tons of raw fonio per year. It uses local materials, traditional techniques, and household equipment: mortars, tubs, calabashes, steaming pots, sieves, matting, kitchen scales, and small utensils. The women sieve, crush, wash, and steam-cook the fonio; then they dry and seal the product in the airtight bags. The most delicate operation is a series of three washes to separate sand from the fine fonio grains.

The women have organized themselves into small working groups, formed for (1) the supply of raw materials, (2) production and packaging, and (3) marketing.

Fonio is considered a prestige food in local culinary customs. Yet, on the Bamako market this precooked product currently sells at a very competitive price: between 500 and 550 CFA Francs per kg. (By comparison, couscous sells at 650-750 CFA Francs.)

This small and homespun operation exemplifies what could and should be done with native grains throughout Africa. It is good for everyone: diversifying the diet of city folks, reducing food imports, and, above all, benefitting the local farmers by giving them a value-added product.

long. Black fonio (*Digitaria iburua*) is taller and may reach 1.4 m. It has 2-11 subdigitate racemes up to 13 cm long.

Although both species belong to the same genus, crossbreeding them seems unlikely to yield fertile hybrids, as they come from different parts of the same genus.[17]

The grains of both species range from "extraordinarily" white to fawn yellow or purplish. Black fonio's spikelets are reddish or dark brown. Both species are more-or-less nonshattering.

Distribution

Fonio is grown as a cereal throughout the savanna zone from Senegal to Cameroon. It is one of the chief foods in Guinea-Bissau, and it is also intensively cultivated and is the staple of many people in northern Nigeria. Fonio is not grown for food outside West Africa.

Cultivated Varieties

There are no formal cultivars as such, but there are a number of recognized landraces, mainly based on the speed of maturity.

Environmental Requirements

Daylength

Flowering is apparently insensitive to daylength.

Rainfall

Fonio is extremely tolerant of high rainfall, but not—on the whole—of excessive dryness. The limits of cultivation (depending on seasonal distribution of rainfall) are from about 250 mm up to at least 1,500 mm. The plant is mostly grown where rainfall exceeds 400 mm. By and large, the precocious varieties are cultivated in dry conditions and late varieties in wet conditions.

Altitude

Although fonio is grown at sea level in, for instance, Sierra Leone, the Gambia, and Guinea-Bissau, its cultivation frequently is above 600 m elevation.

Low Temperature

Unreported.

High Temperature

Unreported.

Soil Type

It is grown mainly on sandy, infertile soils. It can, however, grow on many poor, shallow, and even rocky soils. Most

[17] Information from G.P. Chapman.

varieties do poorly on heavy soils. However, by working with a range of varieties, one can generally adapt the crop to almost all terrains and exposures; for example, to fertile or unproductive conditions: sandy, limy, gravelly, or pebbly soils; slopes; plateaus; valleys; or riverbanks.

4

Pearl Millet

Of all the world's cereals, pearl millet (*Pennisetum glaucum*)[1] is the sixth most important. Descended from a wild West African grass, it was domesticated more than 4,000 years ago, probably in what is now the heart of the Sahara Desert (see map, page 80). Long ago it spread from its homeland to East Africa and thence to India. Both places adopted it eagerly and it became a staple.

Today, pearl millet is so important that it is planted on some 14 million hectares in Africa and 14 million hectares in Asia. Global production of its grain probably exceeds 10 million tons a year,[2] to which India contributes nearly half. At least 500 million people depend on pearl millet for their lives.

Despite its importance, however, pearl millet can be considered a "lost" crop because its untapped potential is still vast. Currently, this grain is an "orphan" among the significant cereals. It is poorly supported by both science and politics. In fact, few people outside of India and parts of Africa have ever heard of it. As a result, it lags behind sorghum and far behind the other major grains in its genetic development. For instance, its average yields are barely 600 kg per hectare and it is almost entirely a subsistence crop; perhaps for this last reason alone pearl millet has attracted little research or industrial support.

Indeed, largely due to neglect, pearl millet is actually slipping backwards. Production in West Africa during the last two decades has increased by only 0.7 percent a year—the lowest growth rate of any food crop in the region and far less than the population's growth rate. Furthermore, even this meager increase has been mainly due to expanding the area cultivated rather than to boosting yields. Elsewhere in Africa the decline has been even more dramatic. Just 50 years ago,

[1] Most taxonomists today believe that the most valid name for cultivated pearl millet is *Pennisetum glaucum* (L.) R. Br. Common synonyms are *Pennisetum typhoides* and *Pennisetum americanum.* The crop is also known as "bulrush millet" and in India it is normally called "bajra."

[2] Exact figures cannot be determined because some countries lump all the millets and sorghum together in their statistics. Also, many countries cannot provide statistics because their pearl millet does not enter organized commerce and is therefore never counted.

Kavango, Namibia. A farmer carrying millet heads to prepare the daily meal. (S. Appa Rao)

pearl millet was of almost incalculable value to millions of rural people in eastern and southern Africa. But over the decades, more and more farmers—especially in southern Africa—have abandoned it and switched to maize.

There are several reasons for this. For one thing, international research efforts have made maize more productive than pearl millet; for another, government incentives have given maize an added financial advantage; and for a third, easier processing has made maize more convenient to use. The momentum for change has now gone so far that maize is often pushed into pearl millet areas to which it is poorly suited and where it cannot perform reliably.

Now, however, a new era may be dawning. Pearl millet is supremely adapted to heat and aridity and, for all its current decline, seems likely to spring back as the world gets hotter and drier. Perhaps the best of all "life-support" grains, pearl millet thrives where habitats are harsh. Of all the major cereals, it is the one most able to tolerate extremes of heat and drought. It yields reliably in regions too hot and too dry to consistently support good yields of maize (or even sorghum). These happen to be the regions most desperately in need of help. It is there that the famines of recent decades have brought mass devastation and death. It is there that expanding deserts are destroying the productivity of perhaps 25 million hectares every year. And it is there that agricultural development could have its greatest humanitarian benefits.

These reasons alone should be sufficient to make pearl millet the target of a global initiative. But this crop has even more promise. Rising climatic temperatures are starting to concern almost all countries. And water is shaping up as the most limiting resource for dozens of the world's nations—including some of the most advanced. Agriculture is usually a country's biggest user of water, so that crops that sip, rather than gulp, moisture are likely to be in ever greater demand. Thus, even for economies that until now never heard of it, pearl millet could quickly become a vital resource.

Agronomically, there is no reason why pearl millet could not (like sorghum) become used worldwide. Indeed, recent research in the United States is showing that its prospects are much higher than most people now think. Already, the crop is showing promise for the heartland of America. It might also become widely used in the hotter and drier parts of Latin America, Central Asia, and the Middle East.[3] It could have a bright future in dry areas of Australia and other countries as well.

[3] Sorghum also has much promise here. It, too, will grow where it is dry, but is best when conditions are cool as well. Pearl millet's important characteristic is its concomitant ability to withstand both heat and low moisture.

Pearl-millet-growing areas in Africa. There are an estimated 14 million hectares of millet in this zone, making it the third most widely grown crop in sub-Saharan Africa. The plant was probably domesticated some 4,000-5,000 years ago along the southern margins of the central highlands of the Sahara. It has since become widely distributed across the semiarid tropics of Africa and Asia. Today, approximately one-third of the world's millet is grown in Africa; about 70 percent of it in West Africa. Africa's major pearl-millet producing countries include Nigeria, Niger, Burkina Faso, Chad, Mali, Mauritania, and Senegal in the west; Sudan and Uganda in the east. In southern Africa, the commercialization of agriculture has resulted in maize partially or completely displacing this traditional food crop. (ICRISAT, 1987; each dot represents 20,000 hectares)

Pearl millet is easy to grow. It suffers less from diseases than sorghum, maize, or other grains. Also, it has fewer insect pests.

The widespread impression that pearl millet grain is essentially an animal feed, unpalatable to all but the desperately hungry, is wrong. The grain is actually a superior foodstuff, containing at least 9 percent protein and a good balance of amino acids. It has more oil than maize and is a "high-energy" cereal. It has neither the tannins nor the other compounds that reduce digestibility in sorghum.

Pearl millet is also a versatile foodstuff. It is used mainly as a whole, cracked, or ground flour; a dough; or a grain like rice. These are made into unfermented breads (*roti*), fermented foods (*kisra* and *gallettes*), thin and thick porridges (*toh*), steam-cooked dishes (*couscous*); nonalcoholic beverages, and snacks.

Grain from certain cultivars is roasted whole and consumed directly. The staple food of the mountainous regions in Niger is millet flour mixed with dried dates and dried goat cheese. This nutritious mixture is taken on long journeys across the Sahara and eaten mixed with water—no cooking required.

Grain from other types is used to make traditional beer. In Nigeria, it is fermented, like maize or sorghum, to produce *ogi*—a traditional weaning food that is still common.

In future, pearl millet may be used in many more types of foods. The fact that it can be made into products resembling those normally produced from wheat or rice should make it acceptable to many more people.[4] With new technology, there seem to be possibilities of using it even to make raised breads (see Appendix C).

All this is not to say that pearl millet is perfect. Indeed, the crop has several serious problems. For one, the raw grain is difficult to process. Many consumers decorticate (dehull) the grain before grinding it into various particle sizes for use in different products. Dehulling by traditional hand pounding produces low yields of flour (around 75 percent) and the product has poor storage stability.[5]

Despite these impediments, this plant's promise is so great that we have devoted the following two chapters to its various types. The next chapter highlights its promise for subsistence farmers—the millions in Africa and Asia to whom pearl millet means life itself. The subsequent chapter highlights commercial pearl millets—the types that are increasingly grown by farmers who produce a surplus to sell.

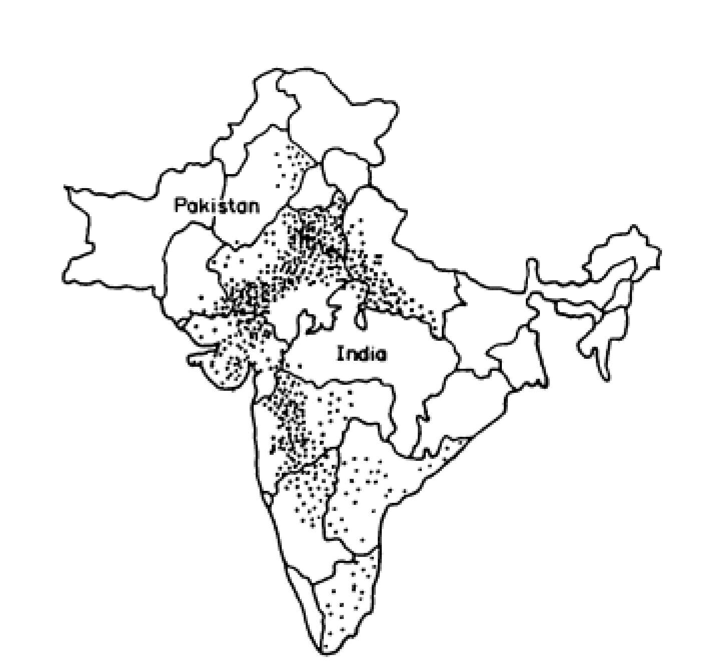
[4] Information H.S.R. Desikachar.

[5] For a probable solution to this problem, see Appendix C. Semi-wet milling and parboiling are two techniques that have recently been shown capable of overcoming the storage stability problem. (Information from D.E. Blyth, ICRISAT).

BAJRA

About 3,000 years ago pearl millet crossed the Indian Ocean and became a vital contributor to South Asia's food supplies. Today it is India's fourth most important cereal, surpassed only by rice, wheat, and sorghum. *Bajra,* as it is called, is currently grown on almost 10 percent of India's food-grain area, and it yields about 5 percent of the country's cereal food. Rajasthan, Maharashtra, Gujarat, and Uttar Pradesh account for nearly 80 percent of the 14 million hectares planted and 70 percent of the 5 million tons of pearl millet grain produced each year.

India's farmers grow some pearl millet under irrigation during the hot, dry months and routinely reap harvests as high as 3 or 4 tons per hectare. But most grow it in the arid areas, particularly where the rainfall is just insufficient for sorghum or maize. Here, the soils are usually depleted in fertility and there is no irrigation. Some plots receive as little as 150 mm of rainfall per year. But pearl millet survives and produces food.



Bajra-growing areas in the Subcontinent. (ICRISAT, 1987; each dot represents 20,000 hectares)

Indian farmer with a sampling of his bajra harvest. (The Rockefeller Foundation)

Indians commonly grind pearl millet and make the flour into cakes or unleavened bread (*chapati*). Some goes into porridges, which may be thin or thick. Much is cooked like rice. The grain is sometimes parched and eaten, the product (known as *akohi, bhunja, lahi,* or *phula*) being similar to popcorn. In some regions, the green ears are also roasted and eaten like a vegetable.

Although small quantities of the grains are used for feeding cattle and poultry, the plant is more often fed to animals as a green fodder. It is well suited for this purpose because it is quick-growing, tillers very freely, lends itself to multiple cutting, and usually has thin and succulent stems.

All in all, pearl millet is not a neglected crop in India. Authorities realize that it stabilizes the nation's food basket. Improved strains, suited to various regions, have been created and released for cultivation. Indeed, its potential is being increasingly exploited, especially as the swelling population requires increased cultivation of marginal land.

LET THEM EAT MILLET BREAD

Millet once played a greater role in the world of cereals for many rural people in eastern and southern Africa, but it has declined in importance over the last 30-50 years because of a preference for maize.

The decline has been compounded by increased research on maize leading to greater productivity of the crop and by the incentives given to maize production through government policies. Maize has been grown, as a result, in dry conditions to which it is not adapted and it has failed too often in these conditions. Governments have come to realize this as well as the farmers themselves.

So it is now necessary to reestablish the importance of millet and sorghum in these drier areas and to do so we must make the production of these crops attractive enough so that they can compete with maize, not only in the worst and most severe droughts but in at least a majority of years. Here is work for the scientists in millet.

But in the long run, even in Africa, maize is not the problem at all. The problem is wheat, or more correctly, bread. Politicians are going to give the people bread. They have been saying this for a long, long time, and they mean it. Technocrats may decry this trend, particularly in tropical areas where wheat cannot be grown satisfactorily, but I can assure you that the protestations will be to little avail. They may slow the process down but they will not stop it. The people of the cities want bread, and the elected officials will ensure that they get it. The people are already exposed to bread and they will ask for it, they will insist upon it, and they will get it.

In many tropical countries it will be very expensive to satisfy this demand unless millet can become bread. And this, too, the politicians recognize and they will support this demand whether efforts can be made to decrease the cost of giving people the food that they demand. So here is something else for the millet scientists to do. Don't ask me how you do it. You know far better than I do. I am just telling you it's got to be done.

From an address by L.D. Swindale
Former Director-General, ICRISAT

NUTRITION

Pearl millet's average composition is given in the tables on the following pages. Some highlights are summarized below.

Carbohydrates usually make up about 70 percent of the dry grain, and they consist almost exclusively of starch. The starch itself is composed of about two-thirds amylopectin (the insoluble component that forms a paste in water at room temperature) and one-third amylose (the soluble component that forms a gel in aqueous solution).

Measurements made on several hundred types have shown that the protein ranges from 9 to 21 percent, with a mean of 16 percent. However, the varieties now used in farm practice have an average of about II or 12 percent. Of the different protein types, prolamine constitutes 40 percent and globulins 20 percent; the presence of an albumin has been also reported, but no gluten. The protein's biological value and digestibility coefficient have been measured as 83 percent and 89 percent, respectively.[6] The protein efficiency ratio has been found to be 1.43, which is even better than that of wheat (1.2).[7]

The grain has about 5 percent fat, roughly twice the amount found in the standard cereals. It is composed of about 75 percent unsaturated and 24 percent saturated fatty acids.

The vitamin values of pearl millet grain are generally somewhat lower than those of maize, although the level of vitamin A is quite good. The carotene value is also good—for a cereal.[8]

Of the grain's edible portion, ash comprises about 3 percent, an amount somewhat higher than in wheat, rice, or maize. The various mineral constituents, accordingly, tend to occur in greater quantities as well. Compared with maize, phosphorus (average 339 mg) is half again as much, iron (average 9.8 mg) is more than three times, and calcium (average 37 mg) is more than five times as much. Traces of barium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, silver, strontium, tin, titanium, vanadium, zinc, and iodine have also been noted.

In feeding trials, pearl millet has proved nutritionally superior to rice and wheat. A review of research in India[9] states that a diet based on pearl millet and pulses is somewhat better at promoting human growth than a similar diet based on wheat. In one trial, for instance, researchers made up vegetarian diets typical of those eaten by the

[6] These figures were determined by feeding experiments on rats at a 5-percent level of protein intake (CSIR, 1966).

[7] This was determined at the 10-percent level of protein intake (CSIR, 1966).

[8] The value reported (as vitamin A) is 22 retinol equivalents (RE). which is not outstanding in itself, but any amount of vitamin A is good for a cereal.

[9] CSIR, 1966.

NUTRITIONAL PROMISE

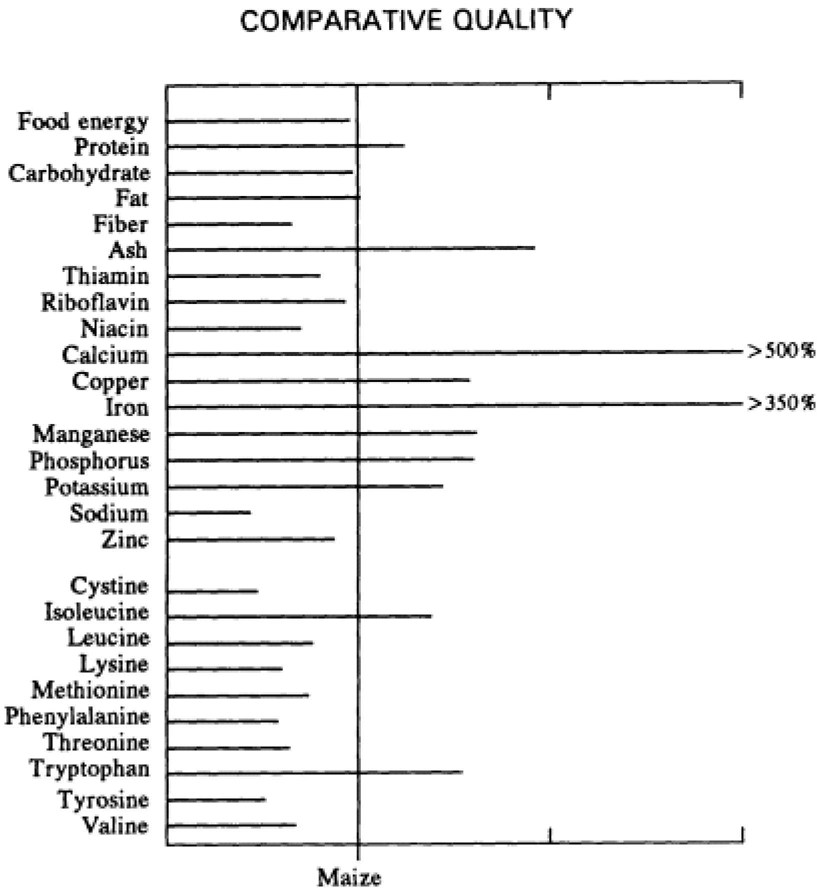
Main Components		Essential Amino Acids	
Moisture (g)	10	Cystine	1.8
Food energy (Kc)	353	Isoleucine	3.9
Protein (g)	11.8	Leucine	9.5
Carbohydrate (g)	70	Lysine	3.2
Fat (g)	4.8	Methionine	1.8
Fiber (g)	1.9	Phenylalanine	4.1
Ash (g)	2.3	Threonine	3.3
Vitamin A (RE)	22	Tryptophan	1.4
Thiamin (mg)	0.31	Tyrosine	3.0
Riboflavin (mg)	0.19	Valine	4.9
Niacin (mg)	2.6		
Calcium (mg)	37		
Chloride (mg)	43		
Copper (mg)	0.5		
Iron (mg)[a]	9.8		
Magnesium (mg)	114		
Manganese (mg)	0.8		
Molybdenum (µg)	190		
Phosphorus (mg)	339		
Potassium (mg)	418		
Sodium (mg)	15		
Zinc (mg)	2.0		

[a] Values range from 1.0-20.7 mg.

The pearl millet grain is nutritious. It has no husk, no tannin, contains 5-7 percent oil, and has higher protein and energy levels than maize or sorghum. The unsaturated fatty acids making up the oil are oleic(20-31 percent), linoleic (40-52 percent), and linolenic (2-5 percent). The saturated fatty acids are palmitic (18-25 percent) and stearic (28 percent).*

In general, pearl millet has a higher protein content than other cereals grown under similar conditions. In 180 pearl millet lines tested

* Information from L.W. Rooney.



in 1972, protein contents ranged from 9 to 21 percent with a mean of 16 percent. It has an excellent amino acid profile and, depending on the variety and perhaps on the growing conditions, the levels of the various amino acids making up the protein can vary by as much as a factor of two. In general, however, the reported values show higher tryptophan, threonine, and valine and lower leucine, but otherwise similar essential amino acids in pearl millet compared with grain sorghum. What is uncertain, however, is the digestibility of pearl millet protein. It is possible that the actual amount of digestible protein is less than that of other major grains.

poor. When pearl millet partially or completely replaced rice, the nutritive value increased appreciably.

Studies conducted on children showed that all the subjects fed diets based on pearl millet maintained positive balance with respect to nitrogen, calcium, and phosphorus. The protein's apparent digestibility was about 53 percent, an amount close to that for finger millet and sorghum proteins, but less than that of rice protein (65 percent). It was also found that pearl millet could replace 25 percent of the rice in a child's diet without reducing the amount of nitrogen, calcium, or phosphorus its body absorbed.

SPECIES INFORMATION

Botanical Name

Pennisetum glaucum (L.) R. Br.[10]

Synonyms

Pennisetum typhoides (Burm.f.) Stapf and Hubbard, *P. americanum* (L.) Leeke, *P. spicatum* Roem and Schult.

Common Names

Angola: massango
Arabic: duhun, dukhon
English: pearl millet, bulrush millet, cattail millet, candle millet
Ethiopia: bultuk (Oromo), dagusa (Amharic)
French: mil du Soudan, petite mil, mil
India: bajra, bajri, cumbu, sajje
Kenya: mi/mawele, mwere (Kikuyu)
Mali: sanyò, nyò, gawri
Malawi: machewere (Ngoni), muzundi (Yao), uchewere, nyauti (Tumbuka)
Niger: hegni (Djerma), gaouri (Peul), hatchi (Haussa)
Nigeria: gero (Hausa), dauro, maiwa, emeye (Yoruba)
Shona: mhunga, mhungu
Sotho: nyalothi
Sudan: dukhon
Swahili: uwele, mawele
Swati: ntweka
Zambia: mawele, nyauti, uchewele (Nyanja), bubele, kapelembe, isansa, mpyoli (Bemba)
Zimbabwe: mhunga (Chewa), u/inyawuthi (Ndebele)
Zulu: amabele, unyaluthi, unyawoti, unyawothi

[10] The widely used name *Pennisetum americanum* is not taxonomically valid, according to most (but not all) authorities.

Description

Pearl millet is an erect annual, usually between 50 cm and 4 m tall. Tillering and branching are not uncommon and are sometimes profuse. The straw is coarse and pithy.

The numerous flowers are tucked tightly around a cylindrical spike (rachis) that can range in length from 15 to 140 cm. This inflorescence is usually greenish yellow, and it may be cylindrical throughout its length or may taper at one or both ends.

The flowers can be either cross-pollinated or self-pollinated. The female part (stigma) emerges before the male part is ready to shed its pollen.[11] As a result, cross-pollination normally occurs. However, where the timing overlaps, some self-pollination can occur.

Grain begins developing as soon as fertilization occurs and is fully developed 20-30 days later. The whole process, from fertilization to ripening, takes only about 40 days.

The seeds range in color from white to brown, blue, or almost purple. Most are slate gray. They are generally tear shaped and smaller than those of wheat. The average weight is about 8 mg. Some thresh free from glumes, while others require husking.

The seeds are quick to germinate. If conditions are favorable, they sprout in about 5 days. Freshly harvested seed may not germinate immediately; however, a dormancy of several weeks after harvesting has been reported.

Pearl millet is a diploid (2n = 14).

Distribution

The two vast areas of West and East Africa where pearl millet is prominent have already been mentioned (see page 80).

Soon after its domestication, the crop became widely distributed across the semiarid tropics of both Africa (15 million hectares) and Asia (14 million hectares). Pearl millet first became known in Europe about 1566 when plants were raised in Belgium from seed said to have been received from India. This form, sometimes known as *Pennisetum spicatum,* is still grown in Spain and North Africa. Pearl millet was introduced into the United States at least as long ago as the 1850s.

Cultivated Varieties

There are vast numbers of types, differentiated by features such as the following:

[11] The first flush of flowering (the female part) is completed in about 2 days; a day later the anthers from the male flowers emerge and a second flush of flowering (the one that produces pollen) continues for a further 2 days. A day or two after that a third flush of flowering begins. This one is from the female-sterile florets.

DOUBLE DIP

Pearl millet's extremely deep roots can reach down into soil layers untapped by other plants. Tests in the southeastern United States have revealed that it can pull up nutrients from residues that have accumulated below the root zones of the previous farm crops.

This finding, should it prove more widely true, has profound implications. Much of the fertilizer now put on crops leaches past their roots where it is not only lost but becomes a pollutant. Having an annual crop that can scavenge the lower layers gives farmers a second shot at the (expensive) fertilizer as well as a tool for cleaning the environment. They might even make a profit from it by selling the pearl millet.

- Quick maturity (about 80 days), medium maturity (100 days or so), or slow maturity (180 days or more)
- Height
- Amount of tillering
- Stem thickness and branching
- Leaf size and hairiness
- Seedhead size, shape, and "tightness"
- Number, length, rigidity, brittleness, and hairiness of bristles
- Size, shape, and color of grain
- The degree to which the glume adheres to the grain.

For pearl millet, the bulk of the systematic breeding has been done in India, but substantial contributions have also come from several African countries, France, and the United States. Most yield improvements have resulted from incorporating genes from African varieties into Indian breeder stocks. However, a breakthrough came in the late 1950s when plants carrying cytoplasmic male sterility were discovered. This genetic trait made hybrids a practical possibility. Today, single-cross pearl-millet hybrids, using male-sterile seed parents, are the basis of vigorous private and semi-public seed industries, especially in India (see chapter 6, page 111).

Environmental Requirements

Daylength

Pearl millet is usually a short-day plant (see next chapter), but some varieties are daylength neutral.

Rainfall

Although the crop is grown where rainfall ranges from 200 to 1,500 mm, most occurs in areas receiving 250-700 mm. The lowest rainfall areas rely mainly on early-maturing cultivars. Although very drought resistant,[12] pearl millet requires its rainfall to be evenly distributed during the growing season. (Unlike sorghum, it cannot retreat into dormancy during droughts.) On the other hand, too much rain at flowering can also cause a crop failure.

Altitude

Pearl millet is seldom found above 1,200 m in Africa, but occurs at much higher altitudes elsewhere (for instance, in western North America).

Low Temperature

The plant is generally sensitive to low temperatures at the seedling stage and at flowering.

High Temperature

High daytime temperatures are needed for the grain to mature. In Africa's pearl millet zone, temperatures are typically above 30°C.

Soil Type

Like most plants, pearl millet does best in light, well-drained loams. It performs poorly in clay soils and cannot tolerate waterlogging. It is tolerant of subsoils that are acid (even those as low as pH 4-5) and high in aluminum content.

Related Species

Pearl millet has many relatives. A number are quite troublesome. In much of Africa, for instance, wild *Pennisetum* species manage to get their pollen in, and this cross-pollination quickly reduces the crop's productive capacity. The hybrid swarms of weedy "half-breeds" (called *shibras* in West Africa) are common contaminants in the farmer's crop. Whereas the cultivated races have broad-tipped persistent spikelets and large, mostly protruding grains, the wild species have narrower, pointed spikelets. Also, their grains are smaller, entirely enclosed by husks, and prone to fall out (shatter). Luckily, the weedy species did not accompany the crop to India.

Although hybridization and introgression between the crop plants and the wild relatives is a problem for farmers, it can be a blessing for plant breeders, giving rise to new forms both of the crop and of the weed. (see page 121).

[12] The northern limit of sorghum in West Africa is around the 375-mm isohyet; that of pearl millet is further north—around the 250-mm isohyet. The crop's drought resistance comes from its rapid growth, short life cycle, high temperature tolerance and developmental plasticity.

5

Pearl Millet: Subsistence Types

Pearl millet is the staple of what is perhaps the harshest of the world's major farming areas: the arid and semiarid region stretching over 7,000 km from Senegal to Somalia (almost one-sixth of the way around the globe at that latitude). There, on the hot, dry, sandy soils, farmers produce some 40 percent of the world's pearl millet grain.

How to help these farmers—who live in the often drought-devastated zone on the edge of the world's biggest desert and who have no access to irrigation, fertilizer, pesticides, or other purchased inputs—is perhaps the greatest agricultural challenge facing the world. The answer may lie in their age-old staple, pearl millet.

Indeed, there is probably no better cereal to relieve the underlying threat of starvation in the Sahel, the Sudan, Somalia, and the other drylands surrounding the Sahara. Millions entrust their lives to this single species every day, and, of all the peoples on the planet, they are the ones most needing help. Yet, at the moment, pearl millet suffers from neglect and misunderstanding—in part because the crop grows in some of the poorest countries and regions and in some of the least hospitable habitats for humans (including research workers). People have thus unjustly stigmatized it as a poor crop, fit only for interim support while something better is located.

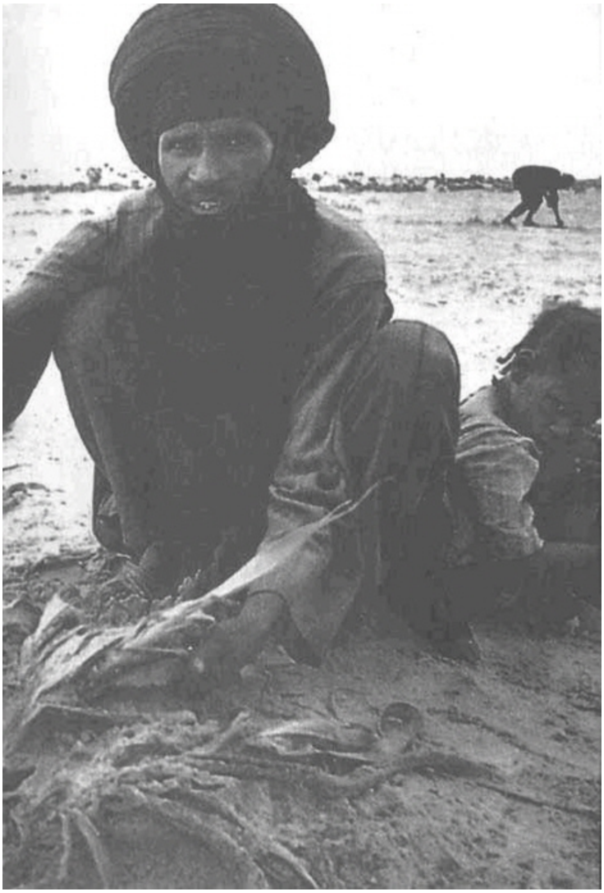
This chapter's purpose is to counter that misguided notion.

SUBSISTENCE MILLETS

Most pearl millets grown in Africa are necessarily oriented toward survival under harsh conditions rather than high yields.[1] For want of a better name, we have called them "subsistence types."

To any outsider used to the robust look of wheat, rice, or maize, subsistence pearl millets may seem puny, unproductive, and downright unworthy of consideration. To an agronomist or cereal breeder, they

[1] The next chapter discusses pearl millet varieties that are adapted to commercial production and more salubrious sites. They tend to be productivity oriented.



FARMING ON THE FRINGE

Pearl millet is the last cereal crop of arable farming on the edge of the desert—beyond it there is only pasturing and open grazing. There is not a more drought-tolerant cereal crop to relieve the threat of starvation. When it fails, nothing else can be substituted. Thus, millions are forced to entrust their lives to this plant. It is not an easy bargain to make.

Most of Africa's pearl millet is grown where the danger of drought is ever present; where the landscape abruptly changes between the wet and dry seasons; where the rains are sometimes limited to only a month or two or three; and where utter aridity prevails the rest of the time.

It seems a cruel irony that the most destitute of people are forced to depend upon foods that they must produce for themselves in the harshest lands. But pearl millet has "rusticité," a French term implying that it will produce *something* no matter what. Droughts, floods, locusts, diseases, and other hazards may hurt, but the plant produces food nonetheless. All other grains, on the other hand, are more vulnerable and more subject to complete collapse. It is remarkable that any crop can cope with the sites where pearl millet is grown. Local cloudbursts can dump the year's precipitation in a few hours. On crusted and hard soils, such deluges result in massive rushing runoff, heavy erosion, and the nearly complete loss of desperately needed moisture. Early season rains are preceded by severe dust storms that damage, bury, and desiccate tender emerging seedlings. Scorching heat can kill an entire crop before it becomes established.

Because of problems like these, the threat of crop failure is omnipresent. Farmers must repeat their sowings, often two or three times. Most sow more area—and in widely separated sites-than they anticipate getting a harvest from. During the planting period they may scatter seeds continually wherever their herds trample the soil, and thereby give the seeds a chance to survive. To farmers elsewhere, tossing a few seeds in cow tracks may seem futile, but to those of the Sahel it can mean life itself.

The pain of growing crops on the desert fringe. Pearl millet underpins millions of desperate lives, including this Fulani farmer in Niger. "I will not plant again," he told the photographer after a rainstorm flattened his seventh millet planting that year. Even his resilient subsistence-type pearl millet has succumbed. Most plantings in this region are lost to drought or sandstorm; this one, ironically, to a flash flood. (Steve McCurry)

look particularly terrible. The plants perform poorly even when they are unstressed. They are tall and top-heavy; they are generally photosensitive; they exhibit low rates of fertilizer response; they have low harvest indexes; and they are localized in adaptation so that even the best of them cannot be easily moved around for use in other places. Above all, they are low yielding—averaging only around 500 kg per hectare.

In reality, though, subsistence pearl millets are some of the most remarkable food plants to be found anywhere. In the area of West Africa where pearl millet is paramount, the droughts can be fierce, the heat searing, and the rainstorms terrible. The sandstorms are even worse. Early in the growing season, the ever-present winds increase in intensity and often swirl the soil so powerfully that it literally sandblasts the tender seedlings. Then, heated by the Sahara sun, the new-blown sand may "cook" the seedlings before they can grow tall enough to shade and cool the land around their roots. Finally, as the soil dries out, its surface often hardens into a crust so impenetrable that any surviving seeds cannot break through.

Because of conditions like these, crop failure is omnipresent and Sahelian farmers must repeat their sowings, often several times. But of all food crops, subsistence pearl millets tend to survive best—they sometimes survive even in bare Sahara sand dunes.[2] They are cereals for "base-line food security" and give the farmer the best chance of staying alive.

By and large, subsistence pearl millets can:

- Germinate at high soil temperatures;
- Germinate in crusted soil;
- Tolerate some sand blasting in the seedling stage;
- Yield grain at low levels of soil fertility;
- Resist downy mildew;
- Tolerate stem borer and head caterpillar; and
- Hold up reasonably well against the parasitic weed striga.

Few of the scientists' varieties could be relied upon to produce food under conditions of such uncompromising hostility.[3] Some of the "faults" perceived by outsiders are actually of great local importance, as the following examples show.

[2] They are also found in bare dunes elsewhere: on the coastal plain of Yemen, for instance. Information from M.W. Brown.

[3] A reviewer from a large research facility in West Africa sent us the following comment: "The fact is, that after 40 years of [pearl] millet breeding, only one 'improved' line—CIVT—consistently surpasses (but not by much) local cultivars. Breeders' varieties routinely underperform local cultivars, even in on-station trials."

Northern Namibia. An Owambo farmer in front of his harvest holding large, compact heads he has selected for seed to sow next season. (S. Appa Rao)

Late Maturation

Elsewhere in the world, plant breeders have tried to speed up their cereals—to make them mature quickly so that more than one crop can be grown per year; so that weeds, pests, and diseases have less chance of causing destruction; and so that food can be produced where growing seasons are short. This is one reason why subsistence pearl millets look bad: many tend to mature very slowly.

The long growing season certainly leads to problems. Since flowering generally takes place after the rains end, even a brief early drought can hit the plants before there is any chance of forming seed and thereby bringing on total crop failure.

However, to Sahelian farmers the delay is all important. They want the grains to ripen after the rains have ceased. Although agronomically inefficient, it eliminates many drying and storage problems. (The grains can be easily dried, and they do not grow molds.) It probably also reduces problems caused by grain diseases and insects, both of which need moisture to thrive.

For the same reason, some subsistence pearl millets are "open-headed." This, too, is inefficient, and plant breeders elsewhere try to replace loose seedheads with compact ones. For the farmer in much of Africa, however, the open form eliminates many of the drying and storage problems encountered with tight-headed varieties.

The long vegetative growth phase is probably also a major adaptive advantage in this region where the soils are lacking in both moisture and fertility: it gives the roots a chance to explore larger soil volumes. For one thing, this probably contributes to the plant's drought tolerance. For another, it probably helps the plant amass the nutrients necessary to grow a good head of grain. This may take considerable time, because roots grow slowly and because in those depleted soils the release of any remaining mineral nutrients is itself often slow.

A related, subtle feature is that the traditional crop varieties usually mature at the same time. This means that only one generation of birds, insects, and diseases gets a chance to attack the flowers and seeds. Adding a mixture of types that mature successively is a disaster: it provides a "rolling nursery" that builds up multiple generations of pests and diseases that then wipe out all late-maturing types.

Daylength Sensitivity

Many of the world's wild plants (as well as most traditional landraces) are sensitive to the length of day. Modern plant breeders try to eliminate this restrictive trait so the plants they produce can be grown in different latitudes and seasons. But, for the subsistence pearl millets of West Africa, daylength sensitivity is what ensures that grain will

be ready to harvest just at the right time in the dry season. It is the length of day that triggers the plant to flower, not the age of the plants. The yield may be poor if the season has been difficult, but the plant will at least flower and mature whatever grain it can.

By-Products

Traditional rustic varieties tend to be big, tall, leafy plants that perform best when spaced far apart. While these varieties produce massive amounts of greenery (6-12 tons per hectare even under the prevailing circumstances), the harvest index is often less than 20 percent. This means that less than 20 percent of the plant (above ground) is grain and more than 80 percent is stalk and leaves, as compared to 30 percent or more for improved high-yield-potential varieties.

But farmers who must produce almost every necessity right on their own land look at these cereals in totality. To them, there is no such thing as excessive stalk. For anyone who cannot buy fencing, roofing, or fuel, stalks are as valuable as grains. And for those who have a cow or some goats, the leaves are what keep the animals alive during the dry season.[4]

Consumer Preferences

To a subsistence pearl-millet farmer, the kernel characteristics—shape, color, processing qualities, and endosperm texture—can be more important than the absolute yield. A grain is almost worthless if it doesn't have the right (and often very subtle) properties for the type of foods the family eats. Subsistence growers choose among the varieties mainly on grounds of suitability for preparing such dishes as:

- *Toh.* The principal food, served at least once a day in the northern Sahel, *toh* is a stiff porridge prepared by adding pearl millet to boiling water while stirring.
- *Koko.* This is prepared by mixing pearl millet flour with water into a fine paste, which is then put aside in a warm place for a day or two to ferment. The resulting sourdough is then dropped into boiling water to form a thin porridge of creamy consistency.
- *Marsa.* This favorite snack of Ghanaians is a deep-fried pancake, prepared from the leavened batter of pearl-millet flour.

[4] This feature is restricted neither to Africa nor to this crop. Even today in parts of Turkey and Syria wheat straw sells for more per kilo than wheat grain (and wheat, of course, is a high-priced crop). Information from J. Harlan.

Genetic Diversity

Pearl millets grown under truly marginal conditions are usually heterogeneous enough to ensure stable production over seasons with widely differing weather patterns. In a sense, the African farmers for centuries have been performing "population breeding," a technique that is only now becoming popular in science. With this technique, a cluster of genotypes acts as a "cohort" able (collectively) to make the best of varying conditions. The genetically different plants in the "swarm" help create a successful harvest, no matter what hazards the season may bring. Should one type be depressed by weather, pests, disease, or mismanagement, others carry the brunt.

Advancing the qualities of a plant along a broad genetic front helps ensure a reliable—although not maximum—yield. And when your life depends on what you can grow, reliability is the most fundamental need.

WHAT TO DO?

Supporting greater production of subsistence pearl millets is one of the world's most humane endeavors. But improving the plants in this case is probably of secondary importance. Given the already remarkable qualities of these time-tested survival crops, given the infertile soils and harsh climates, and given the resources at the farmer's disposal, it would be difficult to come up with a better plant than he has already.

More important is research to make the farming methods easier, more reliable, and more effective; research to make storing and handling the harvest better and safer; and research to ease the daily drudgery of processing the raw grain into edible forms.

This book is of course designed to highlight promising plants rather than farming, storage, or processing methods. However, during the course of this study we came across some innovative ideas that may help boost the performance and reliability of subsistence pearl millets. We mention them here briefly. In the appendixes can be found ideas on potential breakthroughs in pest control, grain storage, milling, and other pertinent aspects.

REDUCING VULNERABILITY TO CLIMATE

Helping farmers to deal with the uncertainties of the early rains—not to mention the droughts, sandstorms, and high soil temperatures—are perhaps the most valuable interventions that can be made. These

THE DUAL TRACK

In this report we have given equal weight to species for both subsistence and commercial production. This is certainly an uncommon approach: in recent years polarization and even rancor have prevailed between the proponents of each viewpoint. However, in a broad sense, subsistence and commercial farming, although separate, are parallel and equally worthy—a fact not widely recognized by the public and one that sometimes befuddles even the best-intentioned scientific minds.

Subsistence farming is vital to the lives of millions, of course, and strengthening it is perhaps the most humanitarian contribution that can be made to African agriculture. But it is often operationally impossible to reach the neediest in the way they want. To create a new variety—even of a well-understood crop such as wheat—can easily take a decade of dedication and perhaps a million in money. It is therefore clearly impractical to reach, individually, the thousands of subsistence regions, each with its likes and dislikes, needs and desires, climates and conditions.

Although technical farming is not inimical to traditional farming, it is often much criticized by those most motivated to helping the neediest farmers. Everybody wants to help the most poverty stricken, of course. However, there is probably not a single subsistence farmer who doesn't dream of producing a surplus for sale. And that surplus is much more than a way to pay for a daughter's dowry or a transistor radio; it is, after all, the way out of poverty.

For this reason, then, those who are developing modern cultivars and hybrids for use in even the poorest nations are not wrongheaded or misguided. Subsistence farmers may be in the overwhelming majority, but the other farmers are the ones who, producing more than they can eat, feed the nonfarming public—the city dwellers, businessmen, doctors, teachers, tourists, and, yes, even the visiting researchers. Nor is there any reason to deny subsistence farmers a route to prosperity by withholding from them the means for producing commercially desirable varieties. Any nation, to survive and prosper, must help its farmers feed more than themselves.

Commercial farming has different requirements and goals from subsistence farming, but it poses no threat. This can be seen in many parts of the world. Throughout the Middle East, for example, farmers grow rustic and advanced wheats side by side—one for family use, the other for market day. Also, in the highlands of

Peru, Indians commonly grow traditional potatoes for themselves and modern potatoes for the cities.

Some have pointed out that the Green Revolution wheats in India and Pakistan were grown largely for sale. They conclude (rightly or wrongly) that commerce was the main motivation and that no quantum leap in food production can occur in Africa until similar commercial opportunities are available. Thus, despite the current polarized approaches, subsistence farming and commercial farming in the Third World are inextricably linked. Improvements in one can benefit the other.

Traditional Farmers Are Superb, But . . .

Subsistence farmers are to be admired and even emulated. Their techniques have been honed in the uncompromising harshness of an unforgiving climate as well as in the ever-present knowledge that failure means hunger or even death. However, no one should get carried away with the romantic notion that peasants always know best.

In the 1860s, when the United States proposed putting an agricultural university in every state, there was much opposition and many claims that American farmers needed no technical help—that professors in universities could not possibly teach the people of the soil how to farm better. But it proved otherwise—the so-called "land grant colleges" provided the engine of basic knowledge that has driven U.S. agriculture to its current heights.

It was through those universities and similar research facilities that the life cycles of many farm pests were worked out, the effects of fertilizer demonstrated, crop genetics illuminated, soil types and soil micronutrients identified, and myriad other basic facts underlying any farming operation brought to light. With this knowledge, even the most stubborn traditionalists were able to coax more from their land, with less effort and more consistency.

All in all, there are many ways in which a basic biological understanding can benefit the subsistence farmers of the hungry nations. Even the best of those farmers can, in this way, be helped to grow their crops more easily, more reliably, and with higher returns.

In the past, scientific findings were applied mostly to commercial agriculture, but that was because larger scale farmers are usually easier to reach and more susceptible to change. Knowledge is not detrimental to subsistence farming, and the polarization that now pervades rhetoric and thinking worldwide is deplorable.

would provide more secure environments early in the planting season and would do much to reduce a farmer's vulnerability to total crop failure before the crop is even started. Following are six possibilities.

Tillering

The pearl millets grown in the Sahel tend to be nontillering—each seed puts up only a single stem. This adds a major vulnerability because if that stem dies in a drought or sandstorm, for example, the plant is lost.

But certain pearl millets put up as many as five heads—not all of them at once. In this case, then, the destruction of a stem still leaves the plant alive and with a chance to rebound.

Other things being equal, adding some tillering types would dramatically reduce the severity of crop losses in the bad years and it would reduce the need to replant damaged fields. And in the good years when the rains are plentiful and timely, two or three (or perhaps more) stems would all emerge and survive, thereby doubling or tripling the yield.

Deep Planting

In the United States, researchers are studying how different types of pearl millet perform while in the seedling stage. They have found that the seedlings show large differences in the length and in the speed with which they lengthen.[5] By selecting types that produce tall seedlings and rapid elongation they have been able to plant the crop as deep as 10 cm.[6] This gives the newly germinated and highly vulnerable seedling a better chance at surviving: it can reach deeper moisture; it is less likely to be killed if the soil surface dries out; and, if it is a fast grower, it can perhaps get through to the air before the soil crusts over.

Although the tests were done in germinators and greenhouses in the United States, they successfully identified lines possessing improved stand-establishment capabilities of high potential value for the subsistence farmers facing the elements a world away.

Water Harvesting

There are many possible ways to help concentrate moisture at the base of seedlings. A companion report identifies a considerable number.[7] That these are likely to have significant value is suggested

[5] This work has been spearheaded by W.D. Stegmeier.
[6] Highly significant differences in elongation of mesocotyl (MC) and coleoptile (CL) organs were found among 1,100 entries germinated at 30°C with MC and CL lengths ranging from 14 to 130 mm and 6 to 40 mm, respectively.
[7] *More Water for Arid Lands.* For a list of BOSTID reports, see page 377.

by a recent paper on the use of soil imprinting and tied ridges.[8] Both techniques produce little "basins" around the plants where water collects.

In the trials (conducted in an area of West Africa where annual rainfall is 600-900 mm), tied ridges captured 85-100 percent of the rainfall received on the site during the season. Normal ridging or flat planting captured only 55-80 percent—the rest was lost as runoff. Tied ridging also reduced the soil's surface bulk density, maintained soil fertility (by reducing losses of soil nutrients), and improved the soil's water-holding capacity. In the case of the pearl millet crop, tied ridging increased the depth of rooting, the root density, the vegetative growth, and the yields—and it did it in both wet and dry years.

Transplanting

The use of nurseries is one of the oldest strategies to avoid water stress in the seedling stage. For centuries, Asians have transplanted rice seedlings and West Africans have transplanted sorghum seedlings (see page 184). Now farmers in parts of Asia are transplanting maize in the same way. Direct sowing is of course much easier, but wherever catastrophic failure is a probability, transplanting provides added security.[9]

In this process, the seeds are planted not in the fields, but in small irrigated nurseries; they are taken to the fields only after the rains have commenced in earnest. This technique seems particularly promising with subsistence pearl millet (not to mention other crops in this book) because the crop must be established during the least favorable season, the time available is often short, the water supply limited, and the weather unpredictable. On top of all that, the farmer feels pressure to plant early because the family needs food and because the growing season is all too brief.

Transplanting not only overcomes the hazards of the unreliable early rains, but compared with a seeded crop, the transplanted crop is in the field for a much shorter time. It also needs far less water for an equivalent yield, and its resistance to the elements is greater. Growing

[8] N.R. Hulugalle. 1990. Alleviation of soil constraints to crop growth in the upland alfisols and associated soil groups of the West African Sudan savannah by tied ridges. *Soil and Tillage Research* (Netherlands) 18(2-3):231-247.

[9] Vietnam, long familiar with transplanting rice, pioneered the technique with maize in tropical conditions. Today, the cultivation of transplanted maize is widespread in the Red River Delta. The technique has boosted the maize crop from 50,000 hectares a year in 1983-1986 to almost 250,000 hectares in 1990. North Korea also uses transplanted maize these days. In fact, it has been said that without transplanting, the area under maize would probably never have exceeded 350,000 hectares, whereas today it covers about 700,000 hectares.

the seedlings in a nursery also allows the farmer to cull diseased plants and thereby reduce the intensity of infection.

Although transplanting is so far associated mainly with other crops, there seems to be no reason why it couldn't prove most beneficial with subsistence pearl millets. Indeed, in a few parts of India and Africa this is already practiced, and with considerable success.

Mulching

As we have noted, burning-hot soil is one of the major hazards to the newly planted subsistence millets. Anything that could cool the surface of the land would help. Apparently, little or no innovation has yet been applied to this problem, although some tests using shade have resulted in a tenfold increase in survival and yield.[10]

Windbreaks

The "sand-blasting" effect can surely be overcome by various kinds of barriers around (or at least on the windward sides of) the fields. One suggestion is the use of vetiver (*Vetiveria zizanioides*) hedges. This tall, extremely rugged grass would probably be unaffected by the blasting sand as its stems are enclosed in tough sheaths. When the time for planting crops arrives—even at the end of the driest of seasons—this perennial should still be standing stiff and straight and able to battle the wind.[11]

IMPROVING CROP MANAGEMENT

Ideas on helping subsistence farmers handle their crops with less work or higher returns can be found in various books, journals, research-station reports, and PVO newsletters, for example. We have included a few ideas in the appendixes to this volume. It is thus not our intention here to belabor such fairly well-recognized issues as the use of fertilizers, optimum levels of tillage, optimum crop population size, and the use of less-laborious cultivation practices such as hoes, plows, and draft animals.

There are, however, some promising lines of research that fit in with the spirit of innovation that lies at the heart of this book. Following are three examples.

[10] Information from J.H. Williams, who wrote to us saying: "As a point of interest my personal research has shown that millet growth varied tenfold as a result of manipulation of soil surface temperature by 6°C (I used shading techniques), but the same manipulation allowed maize to grow in 40°C air temperatures as well!"

[11] More information on this most interesting grass can be found in the companion volume *Vetiver: a Thin Green Line Against Erosion.* For a list of BOSTID reports, see page 377.

Cropping Systems

Subsistence pearl millets are essential components of traditional agricultural systems. They are usually intercropped with cereals such as sorghum and maize or with legumes such as cowpea or peanut. To most farmers, the combined production is more important than the yield from either crop by itself. This mixed cropping is difficult for today's researchers to deal with, but there are some interesting developments. One is dwarfing.

To reduce the size of a cereal plant is a common strategy (see next chapter). It provides a compact plant that is more resilient, easier to handle, and higher yielding. In the case of subsistence pearl millets, however, dwarfing is done not for such a yield advantage. Researchers have found that simply reducing the plant height can contribute greatly to the associated cowpea and other low-growing legumes.[12] The millet no longer shades its shorter companion, which, with the increased photosynthesis, results in better yields. Initial results in Niger are quite encouraging. Farmers there have adopted dwarf millets eagerly.

Building Tilth

The soil under subsistence pearl millet is usually coarse textured, containing at least 65 percent sand. Such porous sites are not only poor in fertility, they are very poor at holding water. Any rain that does fall tends to drain away below the reach of the roots. Ways to keep it in the root zone would bring marked benefits, both in the crop's yield and its reliability.

It has been found, for example, that leaving crop residues in the field dramatically raises pearl millet yields in West Africa's deteriorating semiarid areas. In three recent trials, grain yields rose by 300, 450, and 550 percent, respectively. The residues not only increased the sandy soil's moisture-holding capacity, they also lowered soil temperatures and boosted fertility.[13]

Biological Fertilization

The areas where subsistence pearl millet is prevalent are usually so remote and so poverty stricken that despite the soil's barrenness commercial fertilizer can seldom, if ever, be used. But all plants, even those as robust as subsistence pearl millets, need food in the form of nitrogen, phosphorus, potassium, and a few so-called "micronutrients." How to provide plant foods under subsistence conditions is one of the

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[12] Reddy et al., 1990.
[13] *INTSORMIL Bulletin,* 1990.

PEARL MILLET HELPS NAMIBIA

Namibia's farming lands are among the driest and most unpredictable to be found. Perhaps for that reason, its farmers rely on *mahangu* (pearl millet) to provide the basic foods to keep their families fed. In the north of the country, where two-thirds of the population live, it is the staple.

In the past, Namibia's farmers could hope to obtain only about 300 kg of grain per hectare—a pitifully small amount. Indeed, production was so low that the country had to import maize to feed its people.

In 1986, however, the country asked ICRISAT for help, and 50 highly productive varieties were brought in and planted out for testing. In March 1987, at the new nation's first "Farmers' Field Day," approximately 100 farmers came to see the results. The variety Okashana 1 proved particularly impressive even though the rainfall that season had been only 170 mm (but well distributed). Namibia then requested 200 kg of Okashana 1 seed for multiplication, large-scale testing, and demonstration to farmers. At the March 1988 Farmers' Field Day, 250 visitors showed up to buy Okashana seed. A year later, more than 500 farmers came, and they bought about 4 tons of the seed.

Since this new variety's arrival, Namibia's farmers have reaped bumper harvests. Even using traditional cultivation practices, they doubled their yields. But those who employed better methods obtained yields of 2.4 tons per hectare, about eight times the traditional amount.

Okashana 1 results from intensive plant breeding at ICRISAT, but it still retains its rustic resilience and is especially suited to subsistence farmers' needs. Among its characteristics are high grain yield, large seed size, early maturity, resistance to downy mildew, and ability to mature grain even when end-of-season droughts rob the plants of moisture.

According to Wolfgang Lechner, of the Mahanene Research Station at Oshkati, more than half of Namibia's pearl-millet farmers now grow the new variety. "Okashana 1 gives a light-colored flour that is highly acceptable," Lechner explains. "With this and the increased yields, within a couple of years the country may not have to rely on maize imports any more. That will save us a lot of valuable foreign exchange."

greatest of all agronomic challenges—not just for Africa and not just for pearl millet.

In certain places, deposits of rock phosphate have been located. This almost insoluble phosphorus-containing mineral has seldom been tapped for fertilizer in the past. But it is potentially a major source of phosphate for regions in extremity. Unlike standard soluble fertilizers, it doesn't provide an instant jolt of good nutrition, but it is nonetheless a most valuable source of a prime nutrient that plants need to remain healthy, robust, and high yielding. Certain parts of West Africa have deposits of rock phosphate that could be tapped for this purpose.

For providing nitrogen to a subsistence farmer's crops, probably nothing is more practical than biological sources. Nitrogen can be obtained in this way by:

- Incorporating crop residues or animal manures into the soil;
- Using leguminous food plants (such as cowpea or peanuts) in crop rotations;
- Intercropping with herbaceous soil-building legumes such as stylosanthes or macroptilium; or
- Incorporating nitrogen-fixing tree species such as *Acacia albida* into the fields.[14]

With pearl millet there is also the potential to get nitrogen directly from a beneficial microorganism that can live on its roots. Such nitrogen-fixing symbioses between a plant and a microbe are characteristic of many legumes, but of only a few grasses. Pearl millet is one of those few. It benefits from a nitrogen-fixing bacterium called azospirillum. Recent trials in Maharashtra, India, have shown that when pearl millet plants were inoculated with azospirillum, the yield of both grain and fodder was significantly increased.[15]

[14] This very interesting African tree, which can add nitrogen to the cropping system and also provide important windbreak effects, is described in the companion report *Tropical Legumnes.* For a list of BOSTID reports, see page 377.

[15] A.S. Jadhav, A.A. Shaikh, A.B. Shinde, and G. Harinarayana. 1990. Effects of growth hormones, biofertilizer and micronutrients on the yield of pearl millet. *Journal of Maharashtra Agricultural Universities* 15(2): 159-161.

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Pearl Millet: Commercial Types

Although it is one of the best means for sustaining life in the most desolate and difficult parts of the farming world, pearl millet also grows well under pampered conditions—under irrigation and in equable climes, for example. Because this fact is not widely known, most people dismiss pearl millet as a crop for good lands, pointing out that its low yield, low harvest index, and generally low fertilizer response mean that it cannot match the better known cereals under high-tech management.

However, it is far too early to dismiss pearl millet as a crop for regions that now grow modern maize and wheat and rice. The plant, as we have said earlier, has remarkable qualities, and some of its environmental resilience happens to be of the type that Latin America, North America, Australia, Europe, and others may soon need desperately. Moreover, pearl millet is no longer a rustic relic. Hybrids and other advanced forms are coming available for worldwide use. The old impressions no longer hold.

In fact, a new vision of this ancient crop's potential is becoming clearer from research in the United States, where pearl millet is already exciting increasing interest (see box, page 114). Indeed, fast-maturing types that ripen grain in as few as 90 days after planting and can be harvested by giant combines are now viewed as important resources for a vast belt spanning the nation from the Carolinas to Colorado.

This recognition is starting a new era in pearl millet production. For almost the first time the crop is being seriously investigated with sophisticated methods in the world's finest research facilities. Male-sterile forms, dwarfs, hybrids, and even some very unusual hybrids that produce fertile seed, have all recently been created. So far (at least in the United States), the emphasis has been on producing pearl millet as a feed grain—and with excellent reason: in U.S. Department of Agriculture trials, beef cattle, young pigs, and poultry fed pearl millet grain have grown as well as (or better than) those eating maize (see box).

More and more, however, America's pearl millet proponents are

realizing that they have in their hands a potential new food grain for the nation and for the world.

There are good reasons for that assumption. Despite the current widespread notion that pearl millet is a second-rate cereal, the plant actually has a high potential growth rate—higher even than sorghum. Like maize and sorghum, it has the super-efficient C_4 photosynthesis. Some types mature very fast and can produce two or even three generations a year if conditions permit. And there are other advantages as well. Pearl millet is, for example, "a plant-breeder's dream" and can be developed quickly into numerous and widely different forms (see box, page 122). It is a cross-pollinating species on which several different breeding methods can be successfully employed. And, by a strange twist of genetic luck, it can also be easily inbred.

In terms of large-scale commercial production, therefore, this crop is poised for revolutionary advances. It stands at about the point maize did in the 1930s. Hybrids are known but are not in widespread use; yields are only a fraction of what they might be; and although the basic understanding of the crop's physiology and genetics is still rudimentary, it is beginning to become clear. Seizing the opportunity now could propel pearl millet (like maize since the 1930s) to far higher levels of productivity by using the best of modern techniques. Indeed, pearl millet might well result in a similar leap in food production in many new areas.[1]

Reasons for thinking this are not hard to find. The world's drylands are faced with an increasingly serious food crisis. Already this is becoming clear in the Middle East. For example, in 1989 Syria's parliamentary speaker announced at a meeting called to discuss Arab development and population problems that, unless the Arab world produces more food, one-third of its people will face starvation.[2] In such places the world's most drought- and heat-tolerant cereal obviously has vital promise.

All in all, then, this plant's adaptability to *both* good and bad conditions makes it a potentially outstanding food crop for vast areas of a "greenhouse-afflicted" world where climates may change wildly from decade to decade or even from year to year, and where more and more people must obtain food from hot, dry soils.

The chances for boosting pearl millet's productivity and usefulness are good, but the improvements may not come rapidly. To make the

[1] The increase in food supplies resulting from the creation of hybrid maize is considered to be a triumph second only to that of the Green Revolution (based on wheat and rice) in Asia in the 1960s and 1970s.

[2] "Danger is moving fast and if we do not . . . face it seriously and sincerely we will never be able to overcome the crisis," said Speaker Abdel-Qader Qaddoura, who noted that Arab food consumption was increasing by 7 percent per year, while production was increasing by only a little over 2 percent.

crop a modern and globally useful food resource, varieties with large, dense, spherical, light-colored kernels that taste good are needed. In addition, improved dehulling characteristics are vital if pearl millet is going to be employed in human foods on a truly wide scale.

Eventually, all of these and more seem likely to come about, as can be seen from the following promising lines of development.

HIGH-GRAIN TYPES

The worldwide cereal-breeding advances of the last 100 years have increased rice, wheat, and maize yields dramatically, but, contrary to popular perception, the plants still produce about the same amount of growth (that is, their overall dry matter is largely unchanged). Yields have risen because the plants were reconfigured to reduce the proportion of stems and leaves and increase the proportion of seeds. Usually, this meant reducing the plant height, but sometimes it also meant increasing the number of seedheads per plant.

Such rearranged plants have been the key to the remarkable jump in cereal yields that have occurred in most parts of the world. They respond well to good management; they make it possible to use fertilizer and other inputs profitably; and they create an upward spiral of yield and income that goes far beyond food production alone. For example, they help farmers to rest part of their land to restore its physical condition and fertility.

As of now, however, Africa's pearl millets are not of the rearranged type. After centuries of trying to stretch their heads above the rampant weeds, they are too tall for maximum grain production. In creating excess stalk, they are consuming energy and moisture that could be used to develop more grain.[3] Also, they cannot fully enjoy the benefits of fertilizer because it makes the plants top-heavy so that rain or wind can easily topple them into the dirt. Paradoxically, more fertilizer can mean less yield.

This was the situation of Mexico's wheats before the 1950s when genes from Japanese dwarf varieties helped create short, strong-stemmed plants that could hold their heavy heads up during lashing winds and pounding storms. Strengthening the plant's architecture allowed fertilizer to work to the fullest benefit and was a prime component of the wheats that generated the Green Revolution.

A similar transformation is now occurring with pearl millet. Strong-stemmed dwarf types are being put to use for the first time. Such types have already been developed in the United States, for example. Yields of 4,480 kg per hectare have been achieved on research stations, and demonstration plots on farms in 1991 yielded 3,024 kg per hectare.

[3] We are of course focusing here on the interests of the farmer whose main goal is to produce grain. For many subsistence farmers, the stalk is also an important resource.

MILLET IN THE USA

Although pearl millet has long been grown in the United States, few Americans have ever heard of it. That may soon change, however. A number of pioneering researchers see this crop as a valuable grain for the nation. High-yielding cultivars are being selected and bred; even hybrids have been created (see page 119). However, owing to an oversupply of food, pearl millet is currently being developed mainly as a way to feed animals. Recent results have indicated that it has exceptional promise for the American livestock industry.

Part of the research has been done in Nebraska and Kansas, where the plant's tolerance of drought and acid soils, its resistance to pests, as well as its low requirements for nitrogen fertilizer, make it a potential boon to farmers. The experiments showed the plant could fit into multiple cropping systems for the Great Plains region.

Pearl millet might be used as a quality-protein grain for many livestock-feeding purposes. Compared with maize, it had higher crude protein and ether-extract concentrations, as well as higher concentrations of all essential amino acids. Already, it is showing promise for feeding both poultry and cattle.

Poultry

Trials in different parts of Georgia have shown that pearl millet grain can fully replace maize in chick rations. It neither reduced the feed-conversion efficiency nor the rate of weight gain. Indeed, chickens eating pearl millet actually grew faster and healthier than those eating maize, sorghum, triticale, or wheat.

This was an important discovery because although maize is the Southeast's main poultry feed, it grows poorly there and the local poultry industry has to import maize from the Midwestern states. Some observers now conclude that as transportation costs increase, locally grown pearl millet could soon replace the imported maize as the poultry feed of choice. Several other areas of the country where maize is difficult to grow seem likely to switch over as well.

Cattle

Metabolism and feedlot trials in both the Midwest and the Southeast have shown that pearl millet is also good for feeding

Plainview, Texas, 1992. Hybrid pearl millet being harvested. In both the Southeast (mainly Georgia) and Midwest (Kansas and Nebraska) hybrid pearl millets have been created. At about I m tall, they are half the normal height and can be harvested by combine. Big improvements in production have been achieved; grain yields of 3,000 kg per hectare are not uncommon. Commercial varieties, like the one shown, have been released for farm use. (M. Marley)

cattle. The grain's oil content, which is more than twice that of maize or sorghum, gives it a relatively high energy density. Pearl millet has also proved potentially useful as a source of protein.* Compared with maize, it had higher concentrations of both crude protein (about 14 percent of the dry matter) and essential amino acids.

* Christensen et al., 1984.

TEMPERATE-ZONE TYPES

Traditionally, pearl millet has been grown within about 30° of the equator, but these days certain types are already growing each year in various parts of the United States—in Georgia, Kansas, and Missouri, for example—that are far from the equator. Moreover, although the plant is almost synonymous with drought and deserts, it is also growing well in mild and humid locations such as the sandy coastal plains of south Georgia and Alabama.

In these temperate areas of America, pearl millet is potentially invaluable as a summer annual grain crop. Maize is poorly adapted to this region where its own shallow roots (blocked by the acid subsoils) and the common summer droughts result in low yields. Hybrid pearl millet develops deep root systems in these acid soils, resulting in much more dependable yields. Pearl millet also resists midges and the lesser cornstalk borer, two insects that severely affect sorghum. Moreover, no aflatoxin problems have been observed with pearl millet.

In addition, pearl millet is giving the farmers in the Southeast undreamed of flexibility. Whereas maize must be planted within a two-week window in April, pearl millet can be planted at any time between April and July. This means that it can skirt the hazards of summer and still mature a crop before winter chills cut off all growth.

EARLY TYPES

A driving force behind U.S. pearl millet research is the chance that pearl millet might make double-cropping possible. This is now approaching reality. Rapidly maturing cultivars are soon to be released, and these are the types now seen as promising for the belt stretching from the Carolinas to Colorado. Planted in spring, just after the winter wheat has been harvested, they can ripen a crop before autumn, when the next winter-wheat crop needs to be planted. Key to this rotation is pearl millet's inherent ability to tolerate heat as well as drought. The plant survives and yields grain even during the sweltering summer and on the (often meager) moisture left unused in the soil by the preceding wheat crop. No other cereal can do that.

The global value of such precocious pearl millets could be substantial.

TROPICAL TYPES

Although pearl millet is the quintessential dryland cereal, it is also found in some of Africa's wet and humid tropical zones. Much pearl

millet is grown, for example, in relatively high rainfall areas of Ghana. The types there are entirely different from those of West Africa's nearby dry zone. In general, they have seedheads (spikes) that are shorter and fatter; grains that are bigger, rounder, and whiter; and plants that mature much earlier. These differences are so conspicuous that the plants were previously classified as a separate species.[4]

Such types there have been little studied or appreciated by the world at large. Yet they appear to be promising in their own right and are good sources of genes for earliness and large grain size.[5]

The potential of pearl millet for the tropics can be seen in Ghana, where early millet is extremely important to rural people. The type grown there normally matures at the peak of the rainy season, a time when farmers have exhausted their food stocks from the previous harvest. At first, they gather pearl millet when the grains are in the dough stage and are soft and sweet. Usually, the freshly harvested heads are steamed, threshed, and dried. This process—the exact reverse of normal practice—probably makes it possible to recover the immature grains that would otherwise turn to mush when threshed.[6]

SUGARY TYPES

In India, as in Ghana (see above), pearl millet is sometimes roasted and consumed like sweet corn. Here, too, the grain is harvested in the milk or dough stage. This is a facet of pearl millet that has received little (if any) investigation. Yet it is reminiscent of the situation with maize a century or so ago. At that time the practice of eating maize grain in the soft, sweet, doughy stage was known only to a few Indian children and perhaps some adventurous farmers.[7] Today, "sweet corn" is a major food of North America, and a huge research effort has been expended on selecting strains whose grains convert sugar to starch only slowly so that they stay sweet. Canned sweet corn is in fact America's favorite preserved vegetable and has been outselling all the others since World War I.

Pearl millet, too, should have a big future as a sweet treat to be eaten more like a vegetable than a cereal.

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[4] *Pennisetum gambiense* Stapf & Hubb. Today, however, they are considered to belong to race *globosum* of *Pennisetum glaucum* native to Ghana, Togo, Benin.

[5] Appa Rao et al., 1982.

[6] This is a fascinating tradition, well worthy of study and emulation. See section on parboiling, page 301.

[7] Sweet corn was not seen by the first colonists who reached North America, and when it was found in a valley in central New York in 1799 it was not appreciated at first. Some was planted along the coast but evoked no particular interest. Sweet corn began to be cultivated widely only after the Civil War (that is, in the 1860s).

POPPING TYPES

In India pearl millet is commonly popped. Dry grains sprinkled onto hot sand burst like popcorn. The pops are sometimes eaten with powdered sugar or brown sugar (*jaggery*).

The types that pop best have been given little or no special study. But popping is a promising method for bettering this crop (see Appendix C, page 297) and should be investigated further. Select types with round grains and impervious seed coats (so that the steam building up inside can reach the explosive levels necessary for good popping) will probably prove best.

LIGHT-COLORED TYPES

Although most of the pearl millets so far grown are tan or brown, white-grained types for the large-scale commercial production of food for people are now under development. These are attractive to look at and are sweet to the taste. Some have high protein contents. Also known are some yellow-grained pearl millets that are rich in carotene, the precursor of vitamin A. So far, however, they have been little appreciated.

EASY-PROCESSING TYPES

As noted earlier, pearl millet is among the more difficult grains to prepare. For one thing, the whole grain (caryopsis) contains a high proportion of germ. But more important, the germ is embedded inside the kernel and is difficult to remove. It is for this reason that traditional hand decortication often produces low yields of flour (not to mention its tendency to go rancid during storage).

The need for cultivars with improved dehulling properties is critical. Indeed, varieties with large, spherical, uniform, hard kernels that produce high milling yields already exist, but have not been documented systematically or brought into large-scale commercial production.

When pearl millets are processed into food products, there will be a need for larger supplies of more uniform grain with desirable milling properties and acceptable flavor, color, and keeping properties.

CUISINE-SPECIFIC TYPES

Most of the world's cereal breeding is done with foods such as bread, cakes, cookies, crackers, canelloni, or various breakfast

concoctions in mind. But for pearl millet to sell in a big way in Africa it must be good for very different foods. In Africa (as well as in India), the major pearl millet foods are unfermented bread, fermented breads, thick and thin porridges, steam-cooked products, beverages, and snacks. Little or no information is currently available on which pearl millets have the best properties for each of these foods. This is a handicap. Undoubtedly, superior types exist and collections and investigations should be made in the houses of the users themselves. As we have said in the previous chapter, however, it is difficult to quantify, let alone breed for, the organoleptic properties of certain foodstuffs.

QUALITY-NUTRITION TYPES

Contrary to general opinion and oft-repeated statements in textbooks, pearl millet is one of the more nutritious of the common cereals. As has been noted, its grain has more fat than most, and its level of food energy (784 kilocalories per kg) is among the highest for whole-grain cereals. It also has more protein, and its level of the essential amino acid lysine is better than in most cereals.

However, some pearl millet grain may suffer (nutritionally speaking) because it is low in threonine and the sulfur-containing amino acids. Also, its lysine level could still be improved. Of course, the other major grains have the same defect, but in the last few decades high-lysine types have been found in maize, sorghum, and barley. It seems likely that a diligent search through the world's pearl millets with an amino-acid analyzer could disclose something similar.

HYBRIDS

As already mentioned, the development of maize hybrids in the 1930s led to a quadrupling of yields. A similar breakthrough, allowing the practical production of pearl millet hybrids, came in the late 1960s, when the first hybrids were created.[8] High-yielding, hybrids have been in use in India since 1966. Heterosis (hybrid vigor) in pearl millet can be substantial.[9] Indian scientists have succeeded in developing hybrids that can almost double the yield of local cultivars.[10]

[8] These were developed in the United States by Glenn Burton.

[9] Naturally, the types used to make the hybrid must be genetically diverse. The common finding that the hybrids show no increase in vigor apparently is owing to the fact that the types crossed were too closely related. Information from W. Hanna.

[10] In India, hybrid millets are used almost exclusively in irrigated farming. The yields can be spectacular, but they are not relevant to most of Africa's pearl millet production. Even in India, dryland farmers still use the nonhybrid forms.

Today, hybrid pearl millets are being planted in Kansas and Georgia. They are half the normal height—only a meter or so tall—and are capable of producing more than 3,000 kg grain per hectare. Their short stature and uniform growth make them amenable to harvest by combine. Commercial varieties are now being released to farmers.[11]

APOMICTIC TYPES

As is well known, hybrids have the limitation that farmers must buy new seed every year or so. Although in many countries this is now a routine part of farming and is seldom constraining, the farmer must be able to buy the seed and the suppliers must be able to produce enough and deliver it on time for the planting season. In rural Africa that can be a problem.

Forms of hybrids that maintain their production potential from generation to generation are being developed in pearl millet (see box, page 123). These forms, known as apomictic types, are on the verge of being perfected.

TOP-CROSS HYBRIDS

Crop varieties sometimes come to disastrous ends when circumstances change or a new disease arrives. In the case of hybrids, the disaster can be particularly severe because creating a replacement is a long and uncertain process that must start afresh with new genetic material. The whole operation might well take 10 years or more of diligent and dedicated effort. But plant breeders at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India have developed a strategy to keep pearl millet hybrids going indefinitely, even when new diseases arise or conditions change.[12]

Normally, hybrids are developed using two inbred parents of known and uniform qualities. ICRISAT's strategy is to replace one parent with an open-pollinated variety of broad genetic background.

The resulting products, called "top-cross" hybrids, are now being tested. So far they have yielded as well as the best of the old hybrids and yet have shown greater resistance to disease (presumably because they have a wider range of genes).

[11] In Georgia, hybrid seed is produced and sold by a company that raises chickens. It provides the seed to farmers and contracts to buy their crop. The company's incentive is that pearl millet makes a better chicken feed than maize and can be grown locally. (As noted above, summer droughts and acid soils make maize uncompetitive in this corner of the country.)

[12] See Research Contacts for ICRISAT address.

This is all well and good, but it is in the prevention of future difficulties that top-cross hybrids really shine. Should one of them ever succumb to disease, plant breeders can introduce resistance through the open-pollinated parent in just a generation or two (in, say, not more than 2 years). It is possible, therefore, to keep a hybrid strong and secure by performing parallel breeding on the open-pollinated parent as a sort of ongoing genetic preventive maintenance.

The ICRISAT plant breeders are now taking the strategy a stage further and replacing even the sole remaining inbred parent with a hybrid of broad genetic background. This means that the resulting hybrid has even more genetic variability within it. This method helps, too, in reducing the cost of seed production.

WIDE CROSSES

Pearl millet (that is, *Pennisetum glaucum*) will hybridize with a few wild *Pennisetum* species, some of them very distantly related. Crosses with close relatives produce fertile hybrids, thus permitting extensive modifications to the genomes of both. Some hybridization work has already been done involving napier grass (*Pennisetum purpureum*). Pearl millet x napier grass hybrids have been released for perennial fodder supplies in India. the United States, and various other nations.

Two wild and weedy subspecies (*Pennisetum glaucum* subspecies *monodii* and *Pennisetum glaucum s*ubspecies *stenostachyum*) also readily cross with pearl millet. The useful characteristics they can confer include disease- and insect resistance, genes for fertility restoration of the A_1 cytoplasm, cytoplasmic diversity, high yield under adverse conditions, apomixis, early maturity, and many inflorescence and plant morphological characteristics.

Among other possibly useful wild species are *Pennisetum squamulatum, Pennisetum orientale, Pennisetum faccidum,* and *Pennisetum setaceum.*

Pearl millet has also been crossed with species of completely different genera, including buffel grass (*Cenchrus ciliaris*).[13]

In an approach that turns normal practice on its head, at least one researcher is using pearl millet to "improve" its wild relatives. The resulting tough, resilient, almost-wild *Pennisetum* hybrids appear useful for stabilizing desertifying environments, while giving those who live there a chance to get some food.[14]

[13] Read and Bashaw, 1974.
[14] Information from G.F. Chapman.

GENETIC JEWELS

Pearl millet is not now used as a genetic-research organism, but potentially it could be one of the best plants for illuminating details of both traditional and molecular genetics. A by-product from such fundamental science is likely to be new forms that increase the crop's value for meeting food needs.

THE PLANT WORLD'S DROSOPHILA

As a tool for investigating genetic interactions, pearl millet has the promise to rival drosophila, the fruit fly with which researchers have plumbed the details of animal genetics since the 1930s. Consider the following.

- The pearl millet plant is robust and demands so little space that it can grow in a 5-cm pot.
- It matures so quickly that four generations a year are possible. (Some genotypes flower just 35 days after planting; others can be induced into this by employing short daylengths and high temperatures.)
- It produces masses of progeny. A single inflorescence can produce 1,000 or more seeds, and a single plant (if unrestrained) can produce 25 or more inflorescences.
- Its flowers are small but are ideally set up for genetic manipulation. Unlike those on most plants, they are receptive to fertilization *before* shedding their own pollen; researchers can therefore readily cross-pollinate a given flower or merely leave it to self-pollinate.
- Its chromosomes are large and easy to count.
- The plants resulting from cross-pollinations usually grow with pronounced hybrid vigor, so that the genetic interactions are clear.
- There is abundant natural genetic diversity: pearl millet's gene pool encompasses about 140 species or subspecies belonging to the genus *Pennisetum.*
- Many genetic states can be obtained. The different *Pennisetum* species have chromosome numbers in multiples of x = 5, 7, 8, and 9. For each of these, there are various ploidy levels, ranging from diploid to octoploid and beyond. In addition, both annual and perennial species occur. And there are types that are sexual or apomictic (see below).

FATHERLESS GRAINS

Like most plants, pearl millet produces seeds that have the characteristics of both parents. Certain of its relatives, however, produce seeds with only their mother's genes. For them, each new generation is identical to the last.

This situation is known as apomixis. It is not unusual in wild grasses, but to introduce it into crops has been considered too complicated, too expensive, or just too far-out. However, all that is now changing. Within the genus *Pennisetum,* apomictic types have been located in a number of species. If their trait for self-replication can be transferred to pearl millet, profound benefits would result.

For one thing, with apomictic pearl millet the farmer's fields would be safe from genetic drift. No longer would pollen blowing in from wild and weedy relatives downgrade the elite varieties. For another, seed from different apomictic varieties could be mixed, and the farmer would retain the security of natural diversity as well as the productivity of man-made varieties.

For a third, apomictic pearl millet hybrids could be propagated by seeds for an unlimited number of generations without losing their genetic edge. Farmers would no longer have to buy fresh seed every year to enjoy the benefits of a hybrid.

The apomictic types of the wild *Pennisetum* species are not themselves promising as crops. They produce few seeds and have many weedy characteristics. But their gene for apomixis can be transferred to the pearl millet plant. Indeed, significant progress has already been made transferring this gene from the wild African grass *Pennisetum squamulatum* to cultivated pearl millet.* This development could catapult pearl millet into being a leader in high-tech agriculture.

Progress is being made in finding molecular markers associated with apomixis. This association will allow researchers in the future to isolate the gene(s) controlling apomixis and possibly use them to produce true-breeding hybrids in many crops. Indeed, in this way pearl millet's genes have the potential to revolutionize food production around the world.

* This work has been performed by Wayne Hanna at the Coastal Plain Experimental Station in Tifton, Georgia. The full address, as well as a contact for more information on apomixis, can be found in Appendix G, page 342.

Recently, researchers in Zimbabwe have crossed pearl millet with 49 different accessions of napier grass (*Pennisetum purpureum*). In doing so, they generated over 200 hybrids between the two near relatives. This was done not to improve the pearl millet, but to raise the yield and protein content of the napier grass, a widely used forage. The new hybrids yield 30-40 percent more dry matter but also 20-40 percent (9 percent versus 11-13 percent) more protein than the forms presently cultivated by local farmers. (ICRISAT)

SWEET-STALK TYPES

At least two grasses—sugarcane and sweet sorghum (see page 198) produce stems filled with sugar. Apparently, nobody thought to look for this trait in pearl millet until the 1980s, when some Indian scientists stumbled on some during a germplasm-collecting expedition in the southern state of Tamil Nadu.[15] In the area around Coimbatore and Madurai, they found types that at maturity contained more than twice the normal amount of soluble sugars.

These sweet-stalk types had long narrow leaf blades, profuse nodal tillering (with asynchronous maturity), short, thin spikes, and very small grains. They could be easily identified by chewing them at the dough stage.

The sweet-stalk pearl millet is used as a fodder that is usually harvested in September, and a subsequent ratoon crop can be taken for grain and straw. The farmers consider them to be superior feedstuffs because livestock love the sweet stalks.

TYPES OF THE FUTURE

As can be seen from the above, pearl millet contains a wealth of genetic strengths and offers almost countless opportunities for innovation and advancement. Eventually, biotechnology could have a huge impact on such a diverse crop. It could, for example, be used routinely to transfer pieces of DNA from variety to variety or from the large numbers of wild *Pennisetum* relatives (or even from other genera). Probably, it is only a matter of time before techniques for this (by using vectors or electrophoration, for example) are developed.

Such transfers are most effective when the crop's protoplasts (wall-less cells) can be regenerated into whole plants. Although it is not yet possible to regenerate protoplasts in pearl millet, it is possible to regenerate suspension cultures (including those of pearl millet x napier grass hybrids) into whole plants.[16]

Perhaps the best way to codify the enormous diversity of this crop is to create a chromosome map (see box, page 34). This is likely to help make possible all sorts of advances in pearl millet. The task should be easier than with many crops. Pearl millet is a diploid with seven fairly large chromosomes and a large number of genes that are already known and definitively mapped.

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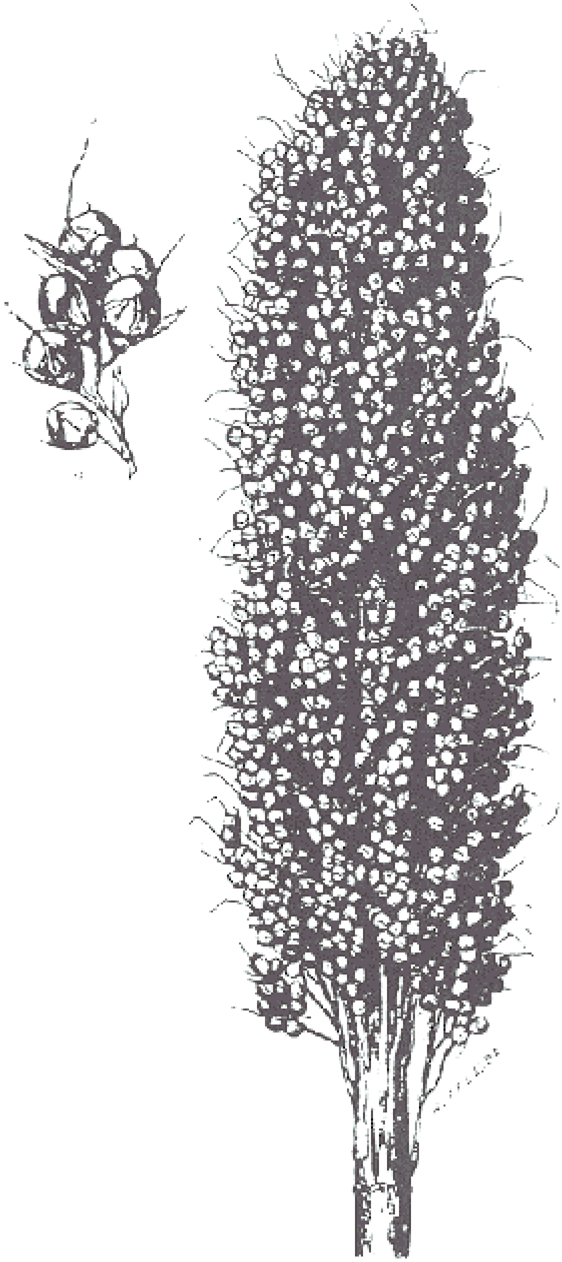
[15] They include R. Appadurai of Tamil Nadu University, Coimbatore, and S. Appa Rao, M.H. Mengesha, and V. Subramanian, of ICRISAT. Their first test was to chew on the stalk. Later, they found that Brix readings can vary from 3 to 16 percent.

[16] All information from W.W. Hanna.



7

Sorghum

To include sorghum in a book on "lost" crops, on the face of it, seems like a gross mistake. After all, the plant is Africa's contribution to the world's top crops.[1] Indeed, it belongs to the elite handful of plants that collectively provide more than 85 percent of all human energy. Globally, it produces approximately 70 million metric tons of grain from about 50 million hectares of land. Today, it is the dietary staple of more than 500 million people in more than 30 countries. Only rice, wheat, maize, and potatoes surpass it in feeding the human race.

For all that, however, sorghum now receives merely a fraction of the attention it warrants and produces merely a fraction of what it could. Not only is it inadequately supported for the world's fifth major crop, it is under-supported considering its vast and untapped potential. Viewed in this light it is indeed "lost."

But this situation may not continue much longer. A few researchers already see that a new and enlightened era is just around the corner. Accorded research support at a level comparable to that devoted worldwide to wheat or rice or maize, sorghum could contribute a great deal more to food supplies than it does at present. And it would contribute most to those regions and peoples in greatest need. Indeed, if the twentieth century has been the century of wheat, rice, and maize, the twenty-first could become the century of sorghum.

First, sorghum is a physiological marvel. It can grow in both temperate and tropical zones. It is among the most photosynthetically efficient plants.[2] It has one of the highest dry matter accumulation rates. It is one of the quickest maturing food plants (certain types can mature in as little as 75 days and can provide three harvests a year).

[1] The amount produced is not known for certain because sorghum's production statistics (at least in some countries) are lumped together with millet's. Annual world production of the two together exceeds 100 million tons, of which 60 million is certainly sorghum. Based on the FAO figures for 1985. the number of hectares under sorghum are: Africa, 18 million; Asia, 19 million; North and Central America, 9 million; South America, 3 million. The main grain production (in millions of tons) was in the United States (28.70), India (10.30), China (an estimated 6.80), Mexico (6.60), Argentina (6.20), the Sudan (4.25), and Nigeria (3.50).

[2] Sorghum uses the C4 "malate" cycle, the most efficient form of photosynthesis. This fundamental advantage of using sunlight efficiently is found in very few food crops among the main ones, only sugarcane and maize.

It also has the highest production of food energy per unit of human or mechanical energy expended.[3]

Second, sorghum thrives on many marginal sites. Its remarkable physiology makes it one of the toughest of all cereals. It withstands high rainfall—even some waterlogging.[4] Recent research in Israel has shown that it also has some tolerance to salt—an increasingly useful feature for any crop these days.[5] But most importantly, it can endure hot and dry conditions. Indeed, it can produce on sites so burning and arid that no other major grain-with the exception of pearl millet—can be consistently grown.[6] Its massive and deep-penetrating roots are mainly responsible for this drought tolerance, but the plant has other drought-defying mechanisms as well. For instance, it apparently conserves moisture by reducing its transpiration when stressed (by rolling its leaves and possibly by closing the stomata to reduce evaporation) and it can turn down its metabolic processes and retreat into near dormancy until the return of the rains.

Third, sorghum is perhaps the world's most versatile crop. Some types are boiled like rice, some cracked like oats for porridge, some "malted" like barley for beer, some baked like wheat into flatbreads, and some popped like popcorn for snacks. A few types have sugary grains and are boiled in the green stage like sweet corn. The whole plant is often used as forage, hay, or silage. The stems of some types are used for building, fencing, weaving, broom-making, and firewood. The stems of other types yield sugar, syrup, and even liquid fuels for powering vehicles or cooking meals. The living plants are used for windbreaks, for cover crops, and for staking yams and other heavy climbers. The seeds are fed to poultry, cattle, and swine. On top of all that, sorghum promises to be a "living factory." Industrial alcohol, vegetable oil, adhesives, waxes, dyes, sizing for paper and cloth, and starches for lubricating oil-well drills are just some of the products that could be obtained.

Fourth, sorghum can be grown in innumerable ways. Most is produced under rain-fed conditions, some is irrigated, a little is grown by transplanting seedlings as is done with rice. Like sugarcane, it can also be ratooned (cut down and allowed to resprout from the roots) to

[3] Exceeding even maize silage, sugarcane, and maize grain. Heichel, 1976.

[4] At least some sorghums can survive standing in water for several weeks. Growth resumes when the water recedes.

[5] Information from D. Pasternak. Sorghum, however, is not as salt tolerant as several millets—selection and management will be needed to get good yields under saline conditions. See companion report. *Saline Agriculture,* for background on the importance of salt tolerance. (For a list of BOSTID publications, see page 377.)

[6] In one drought year the maize (corn) crop was so poor in Mitchell, South Dakota, that the annual "Corn Palace" had to be built out of sorghum. It was a humiliating comedown, but no maize could be found—only sorghum had survived.

provide crop after crop without replanting. It is ideal for subsistence farmers on the one hand and can be completely mechanized and produced on a vast commercial scale on the other.

Finally, sorghum is relatively undeveloped. It has a remarkable array of untapped variability in grain type, plant type, adaptability, and productive capacity.[7] Indeed, sorghum probably has more undeveloped and underutilized genetic potential than any other major food crop.

With all these qualities and potentials, it is small wonder that certain scientists regard sorghum as a crop with a great future. Undoubtedly, as the world moves towards the time when its supplies of food will be insufficient for its supplies of people, this plant will increasingly contribute to the happiness of the human race. This will happen sooner rather than later. Population is projected to almost double within most of our lifetimes. How to feed billions of newcomers on diminishing amounts of prime cropland will likely be the overwhelming global issue of the period just ahead. Obviously, vast amounts of the less fertile and more difficult lands must be forced to produce food. Moreover, if the much feared greenhouse effect warms up the world, sorghum could become the crop of choice over large parts of the areas that are today renowned as breadbaskets, rice lands, or corn belts.

In sum, it seems certain that no matter what happens sorghum will assume greater importance, especially to backstop the increasingly beleaguered food supplies of the tropics and subtropics. For a hot, dry, and overcrowded planet, this crop will be an ever-more-vital resource.

This is in fact already starting. Despite only modest international support, sorghum even now seems to be verging on a global breakout. In the United States, its yield improvements have outstripped those of all other major cereals.[8] In India, it is increasingly employed. And in Mexico, Central America, and the Caribbean—a most unexpected part of the world for this African plant—the most rapid growth of all is occurring.

Indeed, the rapidity with which Mexico has embraced sorghum is little short of spectacular. Before 1953, the crop was so little used in Mexico that, as far as international statistics were concerned, it didn't exist there. However, by 1970 it was being planted on nearly I million hectares, and by 1980 on nearly 1.5 million hectares. The reason is a pragmatic one: sorghum is not only cheaper to produce, it yields about twice as much grain as maize in Mexico (2,924 kg per hectare versus 1,508 kg per hectare in one recent test). Also, where rainfall is unreliable, sorghum is proving the more dependable of the two.

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[7] There is such diversity in this crop that as many as 18 subspecies were once recognized by botanists.

[8] Leng, 1982.

Mexico uses most of its sorghum grain for animal feed, but it is increasingly relying on new, food-quality sorghums. These produce grains suitable for making tortillas, the round flat bread that is Latin America's staple food. In addition, sorghum is also being used to make breakfast cereals, snacks, starch, sugars, and other products that currently come from maize. It is even the basis for some (European-type) beers in Mexico, a country renowned for its brewing skills.

Although these developments demonstrate sorghum's capabilities and almost certainly portend a coming boom in production throughout much of the world, much remains to be done before this crop can truly fulfill its international potential. At present, it has several drawbacks, including the following:

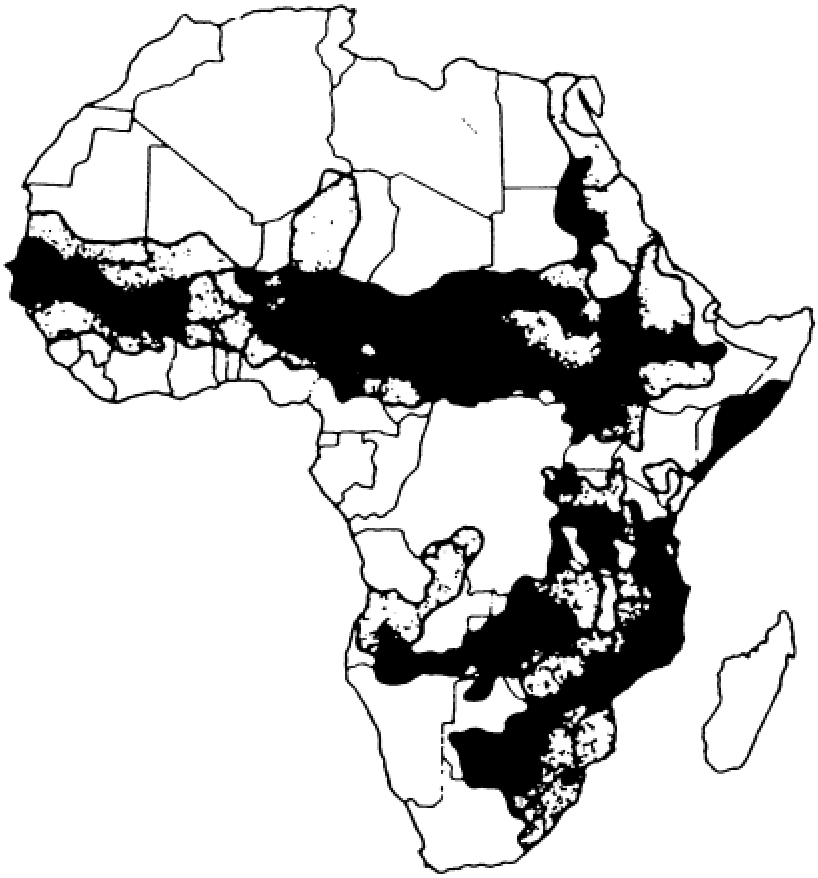
- Lack of status. In global terms, sorghum is being held back by the mistaken prejudice that it is a "coarse" grain, "animal feed," and "food of the peasant classes."
- Low food value. In its overall nutrient composition—about 12 percent protein, 3 percent fat, and 70 percent carbohydrate—sorghum grain hardly differs from maize or wheat. However, sorghum has two problems as far as food quality is concerned. One is tannins, which occur in the seed coats of brown sorghum grains. When eaten, tannins depress the body's ability to absorb and use nutritional ingredients such as proteins. Unless the brown seeds are carefully processed, some tannins remain, and this reduces their nutritional effectiveness.

  The other problem is protein quality, which affects all sorghums, both brown and white. A large proportion of the protein is prolamine, an alcohol-soluble protein that has low digestibility in humans.[9]
- Difficulty in processing. Sorghum is harder to process into an edible form than wheat, rice, or maize.

Ultimately, none of these drawbacks is a serious barrier to sorghum's grander future, but each is a drag that—like a sea anchor in the tide of progress—is holding the crop from its destiny. Moreover, all of them can be overcome, as the following chapters demonstrate.

This plant's potential is so great that we have devoted the following four chapters to its various types. The next chapter highlights sorghum's promise for subsistence farmers—the millions in Africa and Asia (not to mention Latin America) to whom the plant means life itself. The subsequent chapter highlights commercial sorghums—the types that are increasingly grown by farmers who produce a surplus. The chapter that follows highlights specialty sorghums—unusually promising food

[9] The alcohol-soluble fraction makes up about 59 percent of the total protein in normal sorghum. The amount of this indigestible protein is lower in other cereals.



The extent to which Africa stands to benefit from sorghum research can be seen from this map. The crop is perhaps the continent's most widespread and important staple. Beyond the fact that yields can be raised far above the present average, sorghum's adaptation to a wide range of ecological conditions is an enormous asset.

Over the millennia, this ancient food was probably domesticated several times. At least four major types arose in different places. These are shown. One of the oldest, the durra (crook-necked) variety, was eaten in Egypt more than 4,000 years ago. Ethiopia is its center of diversity, and durra sorghum is still the staple food for most of the populace of the Horn of Africa. The region from eastern Nigeria through Chad and western Sudan is a center of diversity for the caudatum race. The region from western Nigeria to Senegal gave rise to the guinea race. The area from Tanzania to South Africa is the center for the kafir race. All of these separate sorghums have fed countless generations.

types that are now little known in a global sense but that have outstanding merits for the future. Finally, there is a chapter on sorghum's promise as a source of energy as well as on other special qualities that can benefit farms and farmers.

AFRICA'S GIFT TO MEXICO

The rise of sorghum in Mexico has been so spectacular that it has been called "the country's second Green Revolution." The crop has become the third largest in terms of area (after maize and beans) as well as in terms of value (after maize and cotton). Between 1958 and 1980, the number of hectares sown expanded by almost 1,300 percent and the amount of sorghum production increased 2,772 percent. More than 1.5 million hectares of sorghum were sown in 1980—more than double the amount of land planted to wheat, Mexico's first Green Revolution crop. Mexico has become the sixth largest sorghum-producing country in the world; only the United States and China used more of this originally African grain.

The fact that sorghum requires less water than maize or wheat is a significant advantage in Mexico, which has large areas of arid land. This has been true even in irrigated areas because the government has sometimes had to limit irrigation water owing to depleted reservoirs. Also, sorghum is now grown in some areas where irrigation has salinized the soil. It requires between two and four irrigations per year, compared to wheat's six or seven. Although average yields per hectare are not as great as those of wheat, they are substantially higher than those of maize.

At the beginning, most of Mexico's sorghum was grown for animal feed. Already, this grain forms a substantial part of the diet of all the chickens, pigs, cattle, sheep, and goats that are raised in the country. Although the animal feed industry also uses

These divisions are of course arbitrary. They are simply a convenient way to present the vast range of this plant's possibilities. There are many areas that overlap and much common ground between the different types, different purposes, and different users. In addition, major advances specifically in Africa's sorghum production are likely to come from methods and technologies that are beyond the scope of the following chapters: from controlling birds, locusts, and parasitic weeds to new approaches to milling, grain storage, and erosion control. These are discussed in appendixes **A** and **B**.

Morelos, Mexico. Farmer with his sorghum crop. (D.H. Meckenstock)

maize, barley, wheat bran, soybeans, and other products, sorghum supplies 74 percent of the raw material used in animal feed in Mexico.

Now, however, more and more food-grain sorghum is being grown (see box, page 166).

NUTRITION

Like other cereal grains, sorghum is composed of three main parts: seed coat (pericarp), germ (embryo), and endosperm (storage tissue). The relative proportions vary, but most sorghum kernels are made up of 6 percent seed coat, 10 percent germ, and 84 percent endosperm.

In its chemical composition, the kernel (in its whole-grain form) is about 70 percent carbohydrate, 12 percent protein, 3 percent fat, 2 percent fiber, and 1.5 percent ash. In other words, it hardly differs from whole-grain maize or wheat. When the seed coat and germ are separated to leave a stable flour (from the starchy endosperm), the chemical composition is about 83 percent carbohydrate, 12 percent protein, 0.6 percent fat, 1 percent fiber, and 0.4 percent ash.

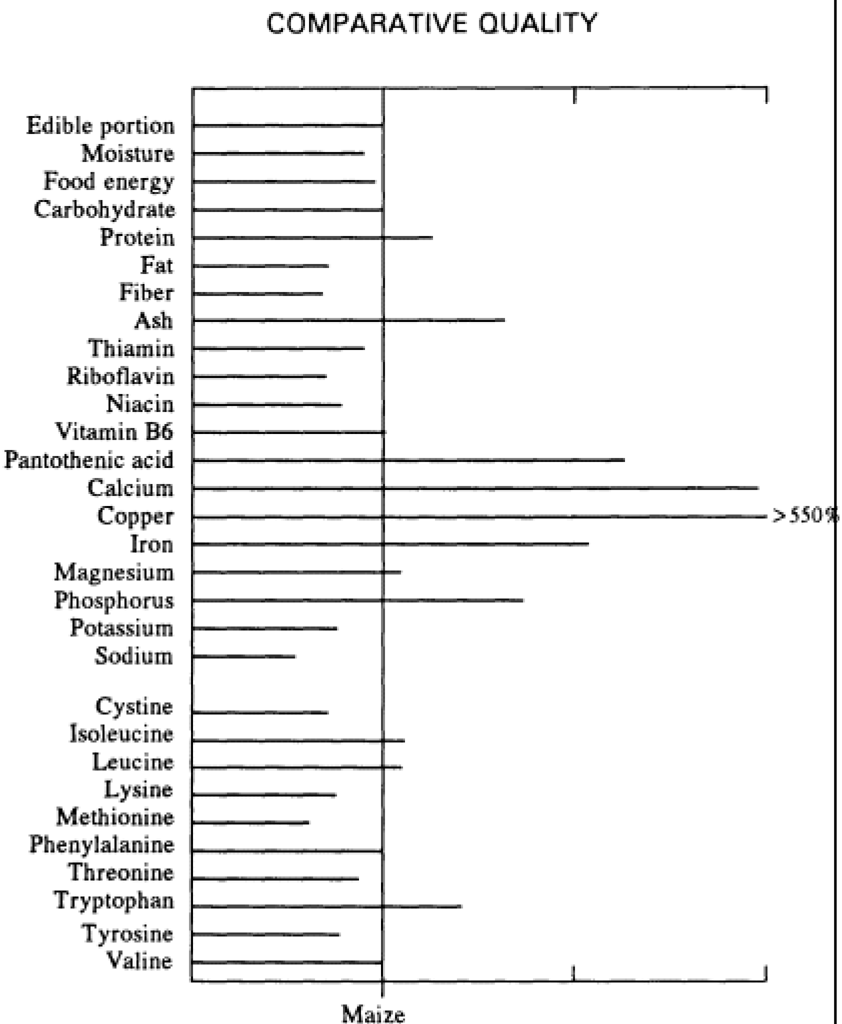
The nutritional components are given in the tables and charts (next page), but some of the details are discussed below.

NUTRITIONAL PROMISE

Main Components		Essential Amino Acids	
Edible portion (g)	100	Cystine	1.3
Moisture (g)	9	Isoleucine	4.0
Food energy (Kc)	356	Leucine	13.5
Carbohydrate (g)	71	Lysine	2.1
Protein (g)	12.0	Methionine	1.3
Fat (g)	3.4	Phenylalanine	4.9
Fiber (g)	2.0	Threonine	3.3
Dietary Fiber (g)	8.3	Tryptophan	1.0
Ash (g)	2.0	Tyrosine	3.1
Vitamin A (RE)	21	Valine	5.0
Thiamin (mg)	0.35		
Riboflavin (mg)	0.14		
Niacin (mg)	2.8		
Vitamin B6 (mg)	0.5		
Biotin (µg)	7		
Pantothenic acid (mg)	1.0		
Vitamin C (mg)	0		
Calcium (mg)	21		
Chloride (mg)	57		
Copper (mg)	1.8		
Iodine (µg)	29		
Iron (mg)	5.7		
Magnesium (mg)	140		
Phosphorus (mg)	368		
Potassium (mg)	220		
Sodium (mg)	19		

In composition sorghum is similar to maize. Starch is the major component followed by protein, fat, and fiber. Compared with maize, however, sorghum generally contains 1 percent less fat and more waxes. Its complex carbohydrates have properties similar to those from maize.

The protein content is quite variable. The American literature reports several instances of levels ranging from 8.3 to 15.3 (these were measured on the milo sorghum that is grown throughout the Midwest). Most samples fall in the 9 percent protein category and are almost always 1 or 2 percent higher than in maize.



However, for human nutrition sorghum protein is "incomplete." It is deficient in critical amino acids, most importantly lysine. Today's standard sorghums provide about 45 percent of the recommended lysine requirement.

Although a primary food for millions of Africans, Asians, and Latin Americans, sorghum is low in protein digestibility. It must be properly processed to improve its digestibility. It is perhaps for this reason that much of Africa's sorghum is subjected to fermentation before it is eaten.

Carbohydrates

Carbohydrate is the grain's major component, with starch making up from 32 to 79 percent of its weight. The remaining carbohydrates are largely sugars, which can be quite high in certain rare varieties of sorghum grains.

The starches in most sorghums occur in both polygonal and spherical granules, ranging in diameter from about 5μ to 25μ (average 15μ). Chemically, the starch is normally made up of 70-80 percent branched amylopectin (a nongelling type) and 20-30 percent amylose (a gelforming type). However, some sorghum starches contain as much as 100 percent amylopectin; others, as much as 62 percent amylose.

In its properties, sorghum starch resembles maize starch, and the two can be used interchangeably in many industrial and feed applications. When boiled with water, the starch forms an opaque paste of medium viscosity. On cooling, this paste sets to a rigid, nonreversible gel. The gelatinization temperature ranges from 68° to 75°.

Protein

Sorghum's protein content is more variable than that in maize and can range from 7 to 15 percent.[10] In most common cultivars, as mentioned above, the kernel contains about 12 percent, which is 1-2 percentage points higher than maize.

The protein's amino-acid composition is much like that of maize protein. Lysine is the first limiting amino acid, followed by threonine.[11] Tryptophan and some other amino acids are a little higher than in maize.

The protein contains no gluten. A large proportion of it is prolamine, a cross-linked form that humans cannot easily digest. In fact, prolamine makes up about 59 percent of the total protein in normal sorghum. This is higher than in other major cereals, and it lowers the food value considerably.

In the long term, sorghums that have less prolamine may come available for routine use. A few of these more nutritious types have already been found: two in Ethiopia (see page 181) and one in the Sudan (page 183), for instance. Until such quality-protein sorghums are perfected, however, sorghum grain needs to be processed if its full protein value is to be realized.

[10] As much as 25 percent has been reported, but these appear to have been in seeds from stressed plants.

[11] Lysine provides about 45 percent of the recommended requirement. (5.44 g lysine per 100 g protein) FAO/WHO (1973).

Fat

Generally, sorghum contains about I percent less fat than maize. Free lipids make up 2-4 percent of the grain and bound lipids 0.1-0.5 percent. The oil's properties are similar to those of maize oil. In other words, the fatty acids are highly unsaturated. Oleic and linoleic acids account for 76 percent of the total.

Vitamins

Compared to maize, sorghum contains higher levels of the B vitamins pantothenic acid, niacin, folate, and biotin; similar levels of riboflavin and pyridoxine; and lower levels of vitamin A (carotene). Most B vitamins are located in the germ.

Pellagra—a disease caused by too little niacin in the diet—is endemic among certain sorghum eaters (as it is among some maize eaters).

Minerals

The grain's ash content ranges from about I to 2 percent. As in most cereals, potassium and phosphorus are the major minerals. The calcium and zinc levels tend to be low. Sorghum has been reported to be a good source of more than 20 micronutrients.

Nutritional Concerns

Recently, the status of sorghum's future as a global food was thrown into disarray by nutritional experiments conducted on malnourished children in Peru. The conclusion was reached that sorghum was "unfit for human consumption."

Part of the problem was due to the fact that the samples used in Peru came from milled flour (comprising only the grain's endosperm) and they were merely boiled into porridge and fed directly. In Africa, by contrast, the whole grain is ground up (so that the protein- and vitamin-rich germ is also included) and often some form of fermentation is also employed.

At the heart of the issue of sorghum's nutritive effectiveness is the above-mentioned fact that almost 60 percent of the protein is in the highly cross-linked form called prolamine. Human digestive enzymes are unable to break up this indigestible protein. Even bodies desperately in need of more muscle, enzymes, blood, and brain continue passing prolamine that might otherwise provide the necessary amino acids.

However, sorghum has a second problem as far as food quality is concerned. Tannins, which occur in the seed coats of dark-colored sorghum grains, block the human body's ability to absorb and use

proteins and other nutritional ingredients. Unless the grain is a low-tannin (yellow or white) type or unless brown seed coats are carefully removed, some tannins remain, and this reduces sorghum's nutritional effectiveness.

Yet a third problem is that when sorghum grain is germinated, a cyanogenic glucoside is formed. In the shoots, enzymes act on this to produce cyanide. This is a potential hazard only with germinated sorghum, and not with the grain itself.

SPECIES INFORMATION

Botanical Name

Sorghum bicolor (L.) Moench

Synonyms

Sorghum vulgare Pers., *S. drummondii, S. guineense, S. roxburghii, S. nervosum, S. dochna, S. caffrorum, S. nigricans, S. caudatum, S. durra, S. cernuum, S. subglabrescens.*

Common Names

China: kaoliang
Burma: shallu
East Africa: mtama, shallu, feterita
Egypt: durra
English: chicken corn, guinea corn
India: jola, jowar, jawa, cholam, durra, shallu, bisinga
South Africa: Kafir corn
Sudan: durra, feterita
United States: sorghum, milo, sorgo, sudangrass
West Africa: great millet, guinea corn, feterita
Middle East: milo

Description

Sorghum comes in many types. All, however, are canelike grasses between 50 cm and 6 m tall. Most are annuals; a few are perennials. Their stems are usually erect and may be dry or juicy. The juice may be either insipid or sweet. Most have a single stem, but some varieties tiller profusely, sometimes putting up more than a dozen stems. These extra stems may be produced early or late in the season. Plants that tiller after the harvest has occurred can be cut back, allowed to resprout, and grown without replanting (like sugarcane).

Soil permitting, the plant produces a deep tap root (see picture, opposite). However, a large number of multibranched lateral roots

For a plant with such a modest leaf area, sorghum's roots are huge. This underground "survival tool" seeks out moisture deep in the soil, equipping the crop for good growth in semiarid climates. The resulting ability to yield grain under dry conditions makes sorghum a crucial tool in the fight against world hunger. (A.B. Maunder, courtesy DeKalb Plant Genetics)

occupy the upper soil levels, particularly the top meter. They can spread laterally up to 1.5 m.

The leaves look much like those of maize. A single plant may have as few as 7 or as many as 24 leaves, according to cultivar. At first they are erect, but later curve downward. During drought they roll their edges together. Rows of "motor cells" in the leaves cause the rolling action and provide this unusual method of reducing desiccation.

The flower head is usually a compact panicle. Each carries two types of flowers: one type has no stalk (sessile) and has both male and female parts (perfect); the other is stalked (pedicellate) and is usually male (staminate).

Pollination is by wind, but self-pollination is the rule. The degree of cross-pollination depends on both the amount of wind and the panicle type, open heads being more liable to cross-pollination than compact ones.

Grains are smaller than those of maize but have a similar starchy endosperm. Most are partially covered by husks (glumes). The seed coat varies in color from pale yellow through purple-brown. Dark-colored types generally taste bitter because of the tannins in the seed coat. The endosperm is usually white and floury as in normal maize, but in some types the outer portion is hard and corneous, as in popcorn.

The crop is always grown from seed. Some seeds show dormancy and will not germinate for a month or so after harvesting. It is a little-known fact that the plant can also be propagated by stem cuttings: nodes along the stem have tissues (primordia) that can produce both roots and sprouts and thereby grow a new plant.

Sorghum is a diploid (2n = 20).

Distribution

This African crop is now known almost worldwide. Dhows, which have been crossing the Indian Ocean for some 3,000 years, probably first carried it away from Africa and took it to India more than 2,000 years ago. It was almost certainly put on board as seamen's provisions. The sorghums of India are related to those of the African coast between Somalia and Mozambique.

Sorghum probably traveled overland from India and reached China along the silk route about 2,000 years ago. It might also have gone by sea directly from Africa: Chinese seamen reached Africa's east coast more than about 1,000 years ago (probably in the eighth century AD), and they may well have carried some seeds home. Cross-pollination with a wild Chinese sorghum[12] seems the most likely reason why the

[12] *S. propinquum,* a diploid member of the *Halepensia* group.

JOWAR

For perhaps 20 centuries, sorghum has been a staple of South Asia. Today, for example, it occupies at least 20 million hectares in India, more area than any other food crop except rice. In monetary terms "jowar," as it is locally called, is perhaps India's third most valuable food plant, exceeded only by rice and wheat.

Outsiders have often dubbed this African grain "the great millet of India." And no wonder. Jowar is an important food over much of the country, and especially in the dry areas of the central and southern states. Millions of Indians eat it. Some use it like rice, but most jowar is milled into flour. More or less white in color, this flour is used especially for making traditional unleavened breads (*chapatis*). Usually the whole-grain flour is employed, but some jowar is also polished to remove the germ and create a flour with a long shelf life. This can be blended with wheat flour (up to 25 percent) for preparing even Western-style raised breads.

Jowar grain is also malted (germinated), and in this form it finds its way into various processed products, including beer and baby foods. The grains of certain varieties pop like popcorn when heated. Indians eat the light and tasty product directly or as a flavoring in baked goods.

And sorghum feeds more than just India's people: its stalks are a major source of fodder. According to some reports, nothing can match its combination of high yield and nutritional quality. Varieties with juicy, sweet stalks have been developed. Cattle find those particularly delicious.

Perhaps 80 percent of India's cultivated sorghums are those (known as "durras") that are the dominant type in Ethiopia, North Africa, and along the Sahara's southern fringes. Many improved strains have been developed. They are grown mainly in the plains and rely on the summer rains, although some are grown under irrigation.

Jowar is notably important on the black-cotton soils, which are notoriously difficult to farm. It is one of the few crops that withstands the wildly fluctuating water tables that produce bottomless mud in the wet season and something resembling cracked concrete in the dry. An ability to extract moisture from deep in the heavy vertisol clay is among the crop's greatest qualities for India.

sorghum now found in China (the kaoliang group) has its own distinctive character.

Broomcorn was first grown in Italy in the 1600s and later spread elsewhere in southern Europe. This form of sorghum has produced most of the Western world's brooms and brushes ever since. Today, Mexico is a major producer.

Horticultural Varieties

This crop comes in such an array of widely different types that various botanists have previously recognized 31 species, 157 varieties, and 571 cultivated forms. However, these all cross readily and without barriers of sterility or differences in genetic balance, so it seems preferable to group them into a single species, *Sorghum bicolor.* Some botanical authorities also include certain wild sorghums, designating them as varieties within the species.

The ease with which cultivated sorghums cross with wild species (such as *S. arundinaceum*) may be a headache for the taxonomist, but it provides great scope for the plant breeder. Indeed, to synthesize new cultivars, a vast range of genetic characters can be brought together in bewildering numbers of combinations. As a result, many cultivars are recognized in Africa, India, the United States, and elsewhere, and new ones are being continually produced (see later chapters and notably page 191).

Environmental Requirements

Sorghum is adapted to a wider range of ecological conditions than perhaps any other food crop. It is essentially a plant of hot, dry regions but takes cool weather in stride and may also be grown where rainfall is high and even where temporary waterlogging can occur.

Daylength

Although many cultivars are insensitive to photoperiod, sorghum is basically a short-day species. Most traditional varieties differentiate from vegetative to reproductive growth when daylengths shorten to 12 hours. This switch to flowering often happens just when the rains diminish, and the crop matures in the dry season that follows, a feature that greatly helps the farmer. Some of these traditional forms are extremely susceptible to photoperiod and reach impossible heights if not planted as daylengths shorten. On the other hand, the dwarf sorghums of the temperate zone are unaffected by daylength and can be planted year-round where climates permit.

Rainfall

Although part of the crop is grown in rainy regions, sorghum is remarkably drought-resistant and is vitally important where the climate is just too dry for maize.

Altitude

Sorghum is grown from sea level to above 3,000 m.

Low Temperature

The plant is killed by frost. Optimum growth occurs at about 30°C.

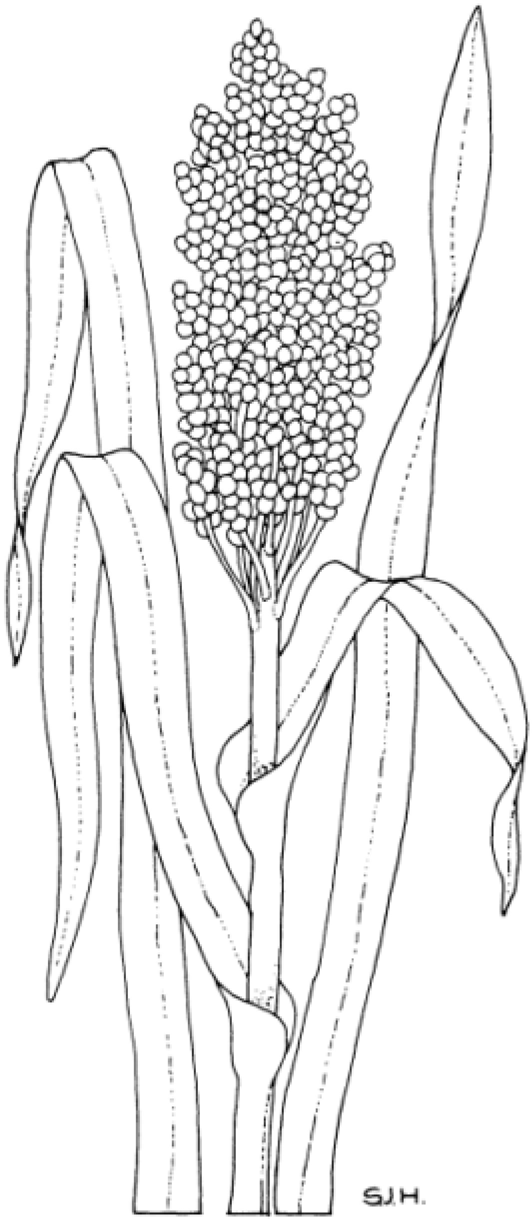
High Temperature

It is essentially a plant of the tropics or subtropics, roughly between 40° of the equator. However, in the United States it is being pushed ever farther into the cooler latitudes.

Soil Type

Sorghum tolerates an amazing array of soils. It can grow well on heavy clays, especially the deep-cracking and black cotton soils of the tropics. It is equally productive on light and sandy soils. It can withstand a range of soil acidities (from pH 5.0-8.5) and tolerates salinity better than maize.

Sweet Sorghum


S.J.H.

8

Sorghum: Subsistence Types

Of all Africa's cereal grains, sorghum is the most important. It shares top billing with pearl millet in the drier zones and with maize in the wetter ones. In fact, Africa devotes more hectares to sorghum and millet than to all other food crops combined.

And sorghum is more important than the bald figures indicate. It is crucial to a substantial portion of the millions who coax from their meager and often declining lands barely enough to sustain life. Many—perhaps most—of those who grow it could hardly survive without this plant. For them, it provides the dietary energy and nutrients that make the difference between health and hunger.

Sorghum is vital in this way for the majority of the most poverty-stricken people in two huge belts that together look like the number 7 superimposed on the map of sub-Saharan Africa. One belt—spanning some 8 degrees of latitude (from approximately 7° to 15°N)—stretches like a giant sash across West Africa from Senegal to Chad. The other, equally huge, runs north to south covering the drier areas of eastern and southern Africa from the Sudan to South Africa (see map, page 131).

The recent past has not been kind to these two vast regions—especially the first. To many observers the picture is already bleak and getting bleaker. The sorghums that provide the subsistence for tens of millions yield on average less than 700 kg per hectare—sometimes much less. Yields have improved little or not at all in decades. Some observers question whether technology can ever make a difference.

The reasons are not unclear. Africa's farmers face a formidable web of interlocking constraints. There are constraints imposed by nature, which seems to take special delight in bedeviling Africa. There are constraints imposed by society and tradition. There are constraints imposed by poverty. And there are constraints imposed by politics, incompetent government, poor roads, and other infrastructural impediments. Subsistence farmers must somehow survive and produce their crops within all of them.

If the constraints were the same throughout Africa, they might be manageable; but th ey differ in degree and kind from farmer to farmer, village to village, valley to valley, and nation to nation. With all these localized and varying limitations, some people conclude that unified advances of the Green Revolution type that swept across India and Pakistan in the 1960s are inapplicable. Perhaps a different approach is needed.

Actually, that approach might come from Africa's own subsistence sorghums. During thousands of years, farmers have selected varieties to match their local conditions and food preferences. These traditional types are already remarkable for their diversity. In Sukumaland in Tanzania, for instance, a single researcher once counted 109 named cultivars—all of them in common use. In Samaru, Nigeria, more than 100 local types have been identified. And in the Lake Turkana area of Kenya there is such a variety of distinctly colored sorghums that just by looking at a grain, farmers claim that they can identify who grew it—a form of "natural bar-coding" that is said to ensure against theft.[1] For Africa as a whole, the number of distinct sorghums must range into the many thousands. Some have been reverently handed down from generation to generation.[2]

These traditional sorghums are not only varied, they can have remarkable qualities. Perhaps centuries of careful observation have gone into their selection. They incorporate features such as:

- Good seedling emergence and strong early root development (to compensate for the normal brevity of the early rains);
- Good tillering (to compensate for erratic early rains as well as shoot-fly attack);
- Long growing cycles (to make best use of infertile soils);
- Resistance to insects (particularly headbugs);
- Resistance to molds; and
- Tolerance of bird pests and striga, a parasitic plant that is an impossible pest in certain regions.[3]

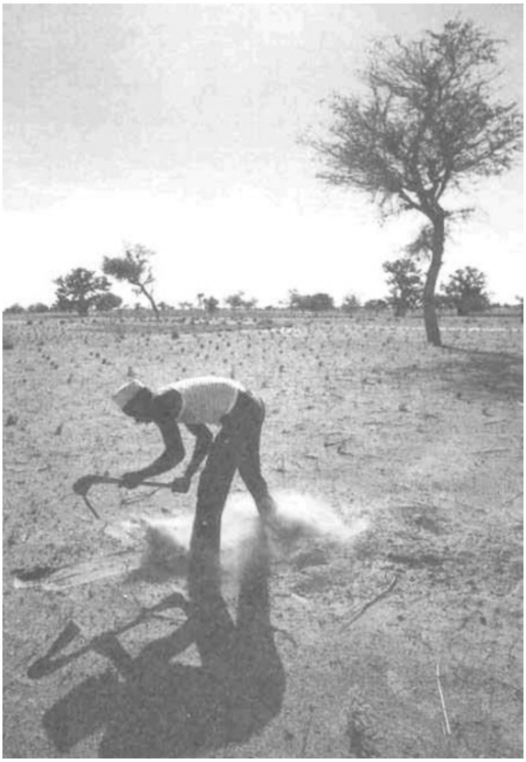
In addition to the agronomic qualities mentioned above, subsistence sorghums have been carefully selected for features that affect the appearance, texture, taste, preparation, or shelf life of traditional foodstuffs. They are mostly grown by women, and are used primarily in the home to prepare local foods.

Traditionally, people consume the grain as a stiff porridge (*toh* or *ugali*), a thin porridge (*uji*), or in a range of fermented beverages.

[1] Information from D.J. Lowe.

[2] All this is made possible because sorghum is predominantly self-fertilizing and a given variety retains its distinctive qualities when it is planted year after year.

[3] Both of these troublesome organisms are described in Appendix A.



Scratching a living in Nigeria's dry northern region, a farmer plants seeds in soil turned to dust. Sorghum's adaptation to a wide range of such marginal conditions is an enormous asset in a crowded world. (Lynn R. Johnson)

Ethiopians form sorghum flour into dough balls that are boiled to form a staple food (*dawa*). In Nigeria, a similar type of dumpling as well as a flaked, dried sorghum-based food are staples. Many people cook the dehulled grain like rice, or grind it into flour like wheat and make biscuits, cakes, or unleavened breads. Some make couscous out of it. Sorghum is also important for brewing native beer or *pombe*.

As has been noted, Africa has two vast sorghum belts. Surprisingly, the conditions in each are so different that varieties perfected in one are seldom useful in the other.

The following conditions prevail in East and southern Africa:[4]

- Most of the crop is planted as a monoculture and laid out in rows.
- The rainy seasons tend to be short and (in most places) to come once a year.
- The plant varieties tend to have shorter stems, tight seedheads (panicles), and relatively high harvest indexes (the ratio of grain to other tissues).
- Birds are often such serious pests that they alone determine what variety is planted, how it is managed, and what level of inputs is applied (see Appendix A).
- The main striga species (notably in southern Africa) is the Asian type (*Striga asiatica*), so that plant breeders can use genes from striga-resistant Indian sorghums.
- Sorghums for brewing and for animal feed are increasingly important.
- Both modern varieties and hybrids have been used, at least on a modest scale, and some types introduced from India have proved extremely successful.[5]

In West Africa, on the other hand, the following conditions apply:

- Little of the sorghum is grown in monoculture; most is planted in mixtures with cowpea, pigeonpea, roselle, and other crops.
- The plants are seldom grown in rows, but are scattered randomly and are often far apart. In the drier parts of this zone the land is neither plowed nor otherwise prepared before planting, except that it is sometimes weeded or burned.
- The plants tend to be tall and lanky and have a low harvest index.[6]
- The plants flower toward the end of the rains, thereby helping the grains escape fungi and sucking bugs, which are prevalent while the rains persist but disappear during the dry months that follow.

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[4] Information based on Carr, 1989.

[5] In Zimbabwe, for instance, this has led to the release of SVI and SV2, both of which have considerable promise. In Zambia, some equally useful hybrids are in the pipeline.

[6] This is hardly a grave limitation because to most subsistence farmers the stalks are a vital fodder and no less valuable than the grains.

- The rainfall can be very erratic.
- Local sorghums are able to produce grains even when severely stressed by drought. (The types grown in higher rainfall areas produce dense, vitreous grains; those grown in dry areas produce floury grains.)
- The seeds are borne in open panicles—a feature generally inimical to high grain yields but one that helps avoid grain molds.
- The main striga is *Striga hermonthica,* a native species. Most of the striga-resistant sorghums from India or even from eastern Africa are susceptible to this parasitic pest.

NEXT STEPS

Actions to open the vast and promising future of subsistence sorghums include those discussed below.

Sharing Varieties7

As noted earlier, truly outstanding sorghums can be found throughout Africa. Many are exquisitely fitted to specific niches for subsistence farmers. Much good could be done merely by making these more widely available. Most are now unknown beyond the valley or village where they are treasured.

Local types are well proven, and moving them within ecological zones could be a powerful way to improve the long-term stability of farm production. Even moving them across ecological zones could become important because there may be increasing climatic change and uncertainty in the future. Farmers now plant cultivars suited to the existing rainfall pattern. However, if the pattern changes (as it did in West Africa in the 1970s) then all local cultivars may become inappropriate. Materials from another area may be the only way to stave off disaster.

Strengthening Farming Methods

To improve sorghum in subsistence production, research on farming methods seems likely to yield quicker benefits than research on breeding plants for higher yield.[8] Some improvements seem simple, obvious, and uncomplicated. For example:

[7] Information from S. Carr.

[8] A 4-year on-farm trial in the early 1980s demonstrated that none of the varieties carefully bred in research trials could outperform local types over all environments when the trials were conducted in the villages. In fact, despite the worldwide sorghum breeding done to date, less than 10 percent of Africa's sorghum area is being planted to nontraditional types from research stations.

Burkina Faso. Sorghum farmer inspects his maturing crop. (H.S. Duggal, courtesy ICRISAT)

- Watering. Studies conducted over the last 20 years in Burkina Faso, for instance, suggest that a little extra water applied when the grains are filling profoundly increases grain yield.
- Fertilization. In some areas, dramatic rises in sorghum grain yields can come from providing nutrients to the soil.[9]
- Legume rotations. Many lands where sorghum grows were infertile to begin with or are now worn out. Nitrogen-fixing leguminous plants could well be the key to rejuvenating most such sites.[10]
- Weed control.
- Water-harvesting and other water-conserving techniques.[11]
- Managing the fields to reduce devastating outbreaks of striga.

Tampering with tradition must be done with caution, however. Some seemingly obvious improvements can prove detrimental in the long run. For example, it is not for nothing that West African farmers grow sorghum plants wide apart. The crop is an excellent scavenger of nutrients and will grow successfully in soils in which maize fails completely, but it must then have room to develop large root systems. Typically, agricultural advisers recommend closer plantings, but where soil fertility is the limiting factor this can reduce the yield. (Of course, if fertility levels are increased, plant populations can be too.)

Another trap for the unwary is the preparation of the land. There is a strong interaction between the choice of variety and how the land has been prepared. In the moister areas, land is cultivated and ridged before planting; elsewhere, however, the seeds are broadcast onto unprepared ground. "Improved" varieties will usually outperform local material *only* where land is cultivated. Local varieties, on the other hand, show little response and cultivating the land before planting can be a waste of time.

Breeding Better Plants

Certain sorghums that yield almost as much as the best grain crops in the world are known (see next chapter). But for helping the subsistence farmer, an 8,000-kg-per-hectare crop is not a suitable target at the present time. Maximum yield is usually not the primary

[9] Unfortunately, however, most traditional sorghums have a low harvest index, and the effects of fertilizers can be disappointing compared with those on maize, for example. The responses vary depending on the poverty of the soil, but in most sorghum-growing areas of the drier zones the yield increase generally is less than half that for maize and is too little to attract many farmers at today's grain and fertilizer prices.

[10] This subject is covered in a companion report, *Tropical Legumes: Resources for the Future.* National Academy of Sciences. 1979. National Academy Press. Washington, D.C. For a list of BOSTID publications, see page 377.

[11] See companion report *More Water for Arid Lands Promising Technologies and Research Opportunities.* National Academy of Sciences. 1974. National Academy Press, Washington, D.C. For a list of BOSTID publications, see page 377.

requirement. Reliability is more important. A yield that can be relied upon year after year is the primary goal of those whose life depends on their harvests. Thus, the immediate need is to improve the yield stability, together with whatever yield increase is compatible with that stability. Average yields of only 1,500 kg per hectare would double production in Africa (not to mention India).

A "CURE" FOR SORGHUM BORERS

It is often hard to see how to improve on crops and methods that subsistence farmers have honed to their needs for hundreds or even thousands of years. However, modern ability to probe deeply into genetics, entomology, soil science, plant physiology, and other sciences can provide insights of great potential value. Here is a recent example.

Subsistence farmers value their sorghum stalks so highly that the grains are sometimes almost a secondary consideration. The stalks are vital for building houses, for fencing, and for firewood (see page 195). But there is a risk in employing them. Larvae of the sorghum stem borer *(Busseola fusca)* shelter inside. Thus, a farmer who keeps lots of stalks around is providing a haven for his worst enemy; eventually, the larvae will turn into adults that will come out in swarms to devastate the next crop.

A Nigerian researcher, A.A. Adesiyun,* has recently been looking into this long-standing problem. By monitoring the popula

Crop-breeding objectives for stabilizing yields for resource-poor farmers in Africa include:

- Raising pest and disease resistance (see below).
- Boosting tolerance to drought, humidity, and other changeable environmental stresses. (These tolerances, however, are pretty high already. In many locations it would be better to breed for higher yield at the existing tolerance levels.)
- Improving grain quality, especially those qualities that are important in storage and processing.

Some of these resistances and tolerances can be bred for outside the local area. "Hot spots" have been identified for many traits of economic importance. Midge, for example, is constantly severe at Sierra Talhada in northeast Brazil; *Busseola fusca* is severe at Samaru in northern Nigeria. An appropriate network of national or regional stations in similar areas could provide a powerful method for screening

and mobilizing masses of useful local germplasm far more rapidly than at present.[12]

tion inside the stalks he has come to appreciate the features that affect the pest and can thereby guide farmers on how to keep their stalks and have good harvests as well.

Naturally, farmers stack the stalks out of weather during the off-season. Adesiyun has found that this is good for the bugs: in the shade only 20 percent die, and all the rest eventually emerge, eager for more sorghum to bore into. However, Adesiyun then found that just stacking the stalks out in the open doubled the number of insects that succumbed. And this was nothing compared to warming the stalks over a fire or spreading them out thinly to bake in the sun for 3 days. This killed a whopping 95 percent of the larvae sheltering inside. The stalks could then be stored safely, even in the traditional stacks in the shade. Moreover, the "cured" stalks could be used around the house or the farm with little risk of infecting the fields with hordes of hungry hoppers.

* Institute for Agricultural Research, Ahmadu Bello University, Samaru, Zaria, Nigeria.

For subsistence use in Africa, it is usually important to breed multipurpose sorghums. Tall plants may be anathema to a cereal breeder, but to many small-scale farmers long stalks are resources vital for fencing, thatching, firewood, and other utilitarian purposes. Those farmers will not switch to a short-stalked type no matter how high-yielding.

Raising Pest Resistance

Among the traditional sorghums of the tropics are some with good resistance to foliar diseases and excellent tolerance to most of the indigenous insect pests. However, to maintain this happy position, research must be continued, especially on the use of systemic insecticides against borers and shoot-fly.[13] Unfortunately, the natural resistance is closely related to the amount of phenolic compounds (particu

[12] Information from S. Carr.

[13] Extracts from the neem tree are promising in this regard. See the companion report, *Neem: A Tree for Solving Global Problems.* National Research Council. 1992. National Academy Press, Washington, D.C. For a list of BOSTID publications, see page 377.

larly the condensed tannins), and these compounds make it harder for people to digest the sorghum grain (see page 179).

THE DILEMMA OF DAYLENGTH

It has been a tenet of modern crop breeding that eliminating sensitivity to daylength is a good thing—the resulting varieties can be grown at many latitudes and in different seasons. But West African subsistence farmers use daylength-sensitive sorghums in an ingenious and sophisticated manner that helps ensure a harvest even in the shortest and most erratic of seasons.

The actual week when the rains will start in the Sahel is unpredictable. The rains may be early, late, or sporadic. However, when the rains will cease is much more consistent. Unfortunately, though, once the rains have stopped, the ground rapidly dries out, leaving little chance for more growth. Thus, although the start of the planting season can vary, the crop must complete its cycle by the given time when the rains come to an end.

Traditional cultivars in West Africa have been selected to flower a little before the rains end, no matter whether the rains began early, late, or on time. The length of day triggers the flowering, not the age of the plant nor the status of the rains.

Local sorghums have evolved over centuries under those austere and fluctuating conditions. They fill out quality grains even under the stress of drought and the boom-and-bust cycles caused by sporadic showers. Introduced varieties and hybrids, by contrast, are "shocked" by the sudden onset and extreme stress of a Sahelian dry season. They seem to collapse physiologically and set floury grains that are useless as food.*

* Information from J.F. Scheuring.

Breeders can also help stabilize yields dramatically by breeding genotypes tolerant of striga. In fact, this is vital. Any "improved" materials lacking striga tolerance could be catastrophic to farmers in areas where this parasite is serious. A striga plant produces tens of thousands of seeds, each of which can remain viable for a decade or more. If susceptible sorghums are introduced, this terrible pest could quickly get out of hand and fill the soil with seeds that act like 10-year time bombs. Luckily, there now seem to be good possibilities for identifying and breeding striga-resistant types (see Appendix A).

Improving Bird Resistance

As noted elsewhere, birds prevent farmers from cultivating the most palatable sorghums in many parts of Africa. Today's bird-resistant types have seed coats containing tannins, which are both bitter and difficult to digest. If a more satisfactory solution can be found, it could be an outstanding contribution to Africa's future, and it would certainly help boost the production of sorghum. New possibilities have recently been discovered (see Appendix A).

Increasing Mold Resistance

In many parts of Africa, molds that destroy grain in the head (panicle) are holding sorghum back. If cultivars more resistant to such damage can be found, then earlier, fast-maturing types could be grown regardless of the humidity during the harvest period. Also, types with dense panicles (a better yielding and more efficient form) could be planted where now only quick-drying open-panicle types are practical. Some strains are inherently resistant to mold regardless of panicle type; these deserve much greater research attention.

Another, relatively easy, intervention is the treatment of seeds against smuts that affect the crop in the seedling stage.

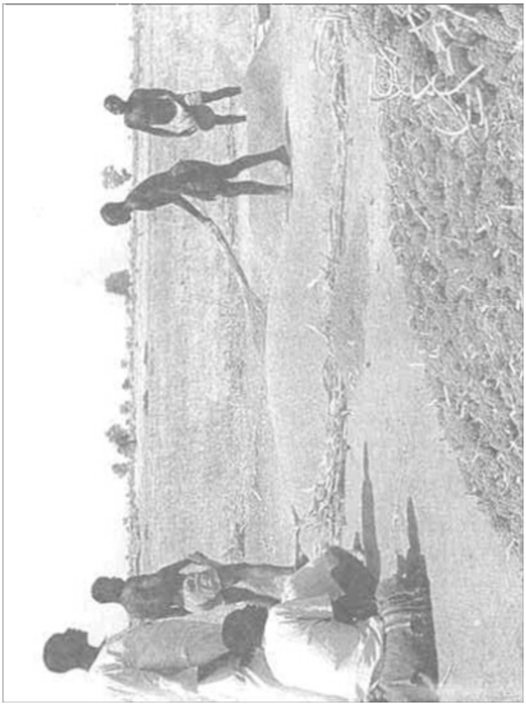
Easing the Burden of Handling

The amount of hand labor needed to prepare the land, control the weeds, and scare away the birds is a serious limit to sorghum production in African subsistence farming. These are significant barriers to increased production. Thus, a major issue raised by any innovation is how much hand labor it demands. This is important to any farmer who has to work the fields by hand. In hoe agriculture one can literally "work oneself to death" by expending more energy than he or she gets out of the harvest.

End Use

As already noted, subsistence sorghums are able to meet the complex array of local requirements. The storage life, processing characteristics, and taste of *toh, ugali, uji, dawa,* and other traditional sorghum-based foods are paramount —more important than the absolute level of yield in the field.

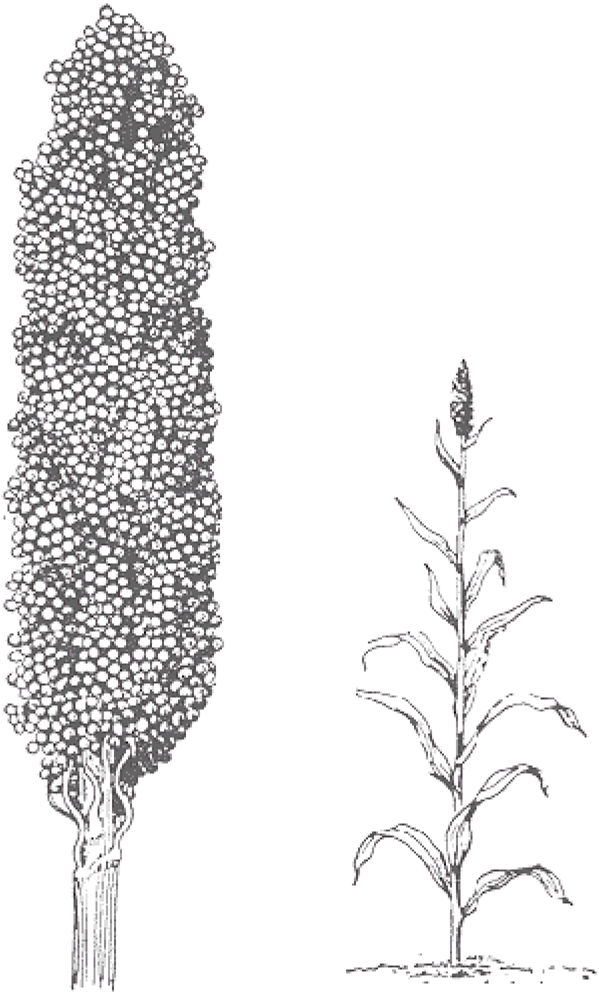
Features that affect traditional foods are hard for scientists to quantify and breed for, especially when the research must be done in centralized research facilities. Subsistence-sorghum breeding is made

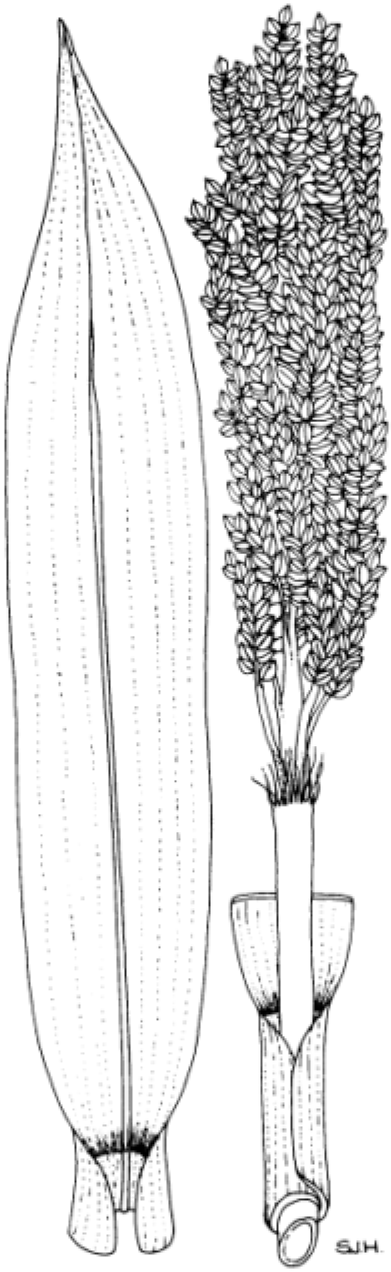


Threshing the harvest. (Zefa Picture Library, London)

even more difficult by the fact that Africa may have as many sorghum dishes as it has cooks.

Already, sorghums improved with exotic germplasm have been rejected because the *toh* they produced didn't keep its texture long enough. (The starch gel collapsed overnight.) The sorghum program in Niger, Burkina Faso, and Mali currently uses small diagnostic tests to evaluate advanced breeding materials for *toh* keeping quality. This approach, by which the plant breeders are directed as much by food technologists and home economists as by yield in the field, is a refreshing and much-needed innovation.





Sorghum caffrorum

9

Sorghum: Commercial Types

Today in Africa, sorghum is grown mostly for subsistence (see previous chapter). It feeds farmers and families who seldom, if ever, have any surplus to sell. But beyond Africa sorghum production is rising, mainly due to farmers who sell their grain so that others can eat. The United States, Mexico, Honduras, and Argentina are just some of the nations now taking advantage of this crop's powerful performance under pampered conditions. Indeed, it is paradoxical that while Mexico's maize is replacing Africa's sorghum in Africa, in Mexico itself the opposite is happening: sorghum is replacing maize in many areas (see box, page 133).

The commercial approach will eventually assist Africa as well. Growing sorghum the way commercial wheat and maize are grown can produce harvests of 3,000 rather than 700 kg per hectare. Indeed, the fact that sorghum has vast untapped commercial potential is important to the future of much of the world. Large areas in Central Asia, northern and central China, South America, and Australia have the potential for expanding the production of sorghum as a large-scale, high-tech competitor of the world's top three grains: wheat, rice, and maize.

Part of the problem in Africa is that so far sorghum has never been developed as a major food for urban areas. Lacking markets, it remains a crop of the small cultivator, consumed largely on the land where it is produced. But this need not—indeed should not—continue as the sole method of sorghum production. As with other crops, sorghum deserves the attention that governments give to any basic food commodity: stockpiling, purchase of surpluses, price supports, research, and policy support, for instance.

One particular restraint on sorghum has been the lack of processed foods—flour, meal, breads, or other materials—for use by those who are not farmers and are not prepared to devote hours of every day making flour from raw grain. The development of a sorghum-based food-processing industry would do much to offset Africa's shift in demand toward imported rice and wheat.

SORGHUM IN AMERICA

When introduced to the United States in the middle of the last century, sorghum was first cultivated on the Atlantic coast. By 1900, it had spread as far west as California. Today, Texas, Kansas, Nebraska, and Missouri are the leading producers. The crop's value now averages about $1.1 billion annually. Much is exported. In 1990, the United States shipped 7,239,000 tons of grain sorghum—almost half of all it produced. Japan was the largest buyer, followed by Mexico.

In the United States itself, grain sorghum is most commonly used as livestock feed. It is fed to cattle (both beef and dairy), poultry, pigs, lambs, horses, catfish, and shrimp. The grain has many industrial uses as well. It is used in foundry-mold sands, charcoal briquets, and oil-well-drilling mud. In addition, sorghum flour is used in the manufacture of plywood and gypsum to build houses as well as in the refining process of potash and aluminum. Some of the ethanol used to fuel American cars is made from grain sorghum.

Although it can be found from the Carolinas to California, sorghum is grown primarily in the Great Plains in the center of the United States. (One dot equals 2,000 hectares.)

Sorghum harvest on the High Plains of Texas. (A.B. Maunder)

There are good reasons for thinking that this may come about. And soon. For example, recent research has shown that sorghum grain can be parboiled to create a fast-cooking, convenient food just as has been done with rice. Also, various projects are under way to produce sorghum flour for sale in stores. In fact, in Botswana sorghum meal is already commercially available.[1] Nigeria, too, is pioneering the processing of locally grown sorghum to replace imported grains (see box).

By and large, the actions needed to boost commercial farming differ dramatically from those needed by subsistence farming. Whereas subsistence farmers may be tied (for reasons of precedent, poverty, environment, or fear of the unknown) to local varieties, commercial farmers are not. They can use newly created sorghum varieties, including hybrids and the best of research-facility results. Their grain is to be sold, probably to markets where the products of perhaps thousands of other farmers are pooled. In this case, the standard varieties demanded by the mass market take precedence, and the cash earned by selling them may pay for fertilizers and other inputs that are beyond the meager means of subsistence growers.

The evidence is persuasive that—just as in the cases of wheat, maize, and rice—sorghum responds dramatically to modern technology. For instance, although subsistence-sorghum yields have remained static at or below 700 kg per hectare, those of commercial sorghums have jumped like those of the Green Revolution crops in Asia. In the 1970s for instance, yields from India's rainfed sorghum increased 50 percent (from 484 to 734 kg per hectare) and Argentina's rose 55 percent. Irrigated yields are considerably higher: in India, about 1,800 kg per hectare is common. Hybrid sorghums can achieve even more: 4,5006,500 kg per hectare are now not unusual yields in the United States, Europe, China, and on commercial farms in Zimbabwe.[2]

In a few cases, sorghum's yield ceiling has been raised to dazzling heights. For example, yields of 13,000 kg per hectare are being reported under special conditions in Mexico.[3] In Argentina and the United States 12,000 kg per hectare have been measured. Farmers in China are said to average 10,000 kg per hectare in certain areas.

Given such advances, sorghum's total global production may eventually match that of maize. And perhaps more important, much of the production will be at sites where maize can barely survive. This will greatly increase the food available in the world.

[1] For information on both parboiling and flour production, see Appendix B.
[2] Mean grain yields in the United States—around 1,200 kg per hectare before the release of hybrids—are now 4,200 kg per hectare.
[3] Vega, 1984.

The rest of this chapter highlights certain forms of sorghum that could help this plant reach its ultimate performance outside the confines and constraints of subsistence farming.

TYPES FOR ALL SEASONS

Sorghum's ultimate promise is perhaps best glimpsed in a research program in Texas and Puerto Rico. The Sorghum Conversion Project, as it is called, is a concentrated research effort that has catalyzed much of the present improvement in sorghum. It changes tall, late, or nonflowering varieties that produce well only in the tropics into short, early-maturing forms that can be used in many parts of the world, including the temperate zones. Its materials are already opening new horizons in sorghum production. Indeed, it is these materials that have led to the big jump in sorghum production in the United States, Mexico, Central America, parts of South America, and elsewhere. All in all, the result of this project could be one of the most significant advances in food production of this era.

In essence, the conversion program has vastly enhanced the source material available to sorghum breeders. It provides seeds of hundreds of types that are not only productive and adaptable, but also contain genetic resistance to insects and diseases and have desirable food qualities. Of the 1,300 lines in the program, more than 400 have been "converted" as of 1991.[4] These select lines are being used to develop gene pools from which breeders can draw genotypes that best fit their local needs and environments.

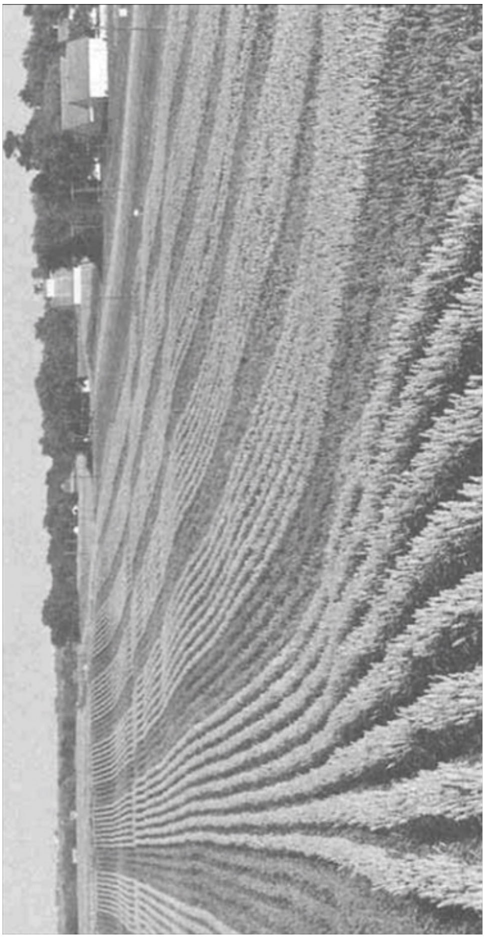
This development is described in more detail in the box (see page172).

HYBRIDS

In the 1930s, America's maize yields were static. With the advent of hybrids, however, yields doubled and redoubled in just two decades. Maize quickly became not only a food but a "living factory," yielding feeds, sweeteners, starch, oil, and myriad industrial raw materials. It rose to such importance that today the U.S. economy would collapse without it.

Sorghum hybrids have much the same inherent potential, as their brief history shows. The first was produced only in 1957, but the effect was electric. Within 4 years, almost all American sorghum growers had switched, and the mean yield nationwide more than doubled from

[4] Information from F.R. Miller.



Texas. Field of hybrid sorghum. America's grain-sorghum production more than quadrupled between the early 1950s and the late 1960s, due primarily to higher productivity resulting from hybrids. (A.B. Maunder, courtesy DeKalb Plant Genetics)

1,280 kg per hectare to 2,750 kg per hectare. Within 10 years, as the hybrids improved, the yield had more than tripled to reach 3,810 kg per hectare. In a little over 20 years it had almost quadrupled to reach 4,190 kg per hectare. Seldom has there been such a rapid increase in grain yields in a cereal crop.

The hybrids were developed by crossing sorghums from southern Africa (the so-called kafir type) with others from Central Africa (caudatum types). The benefits come both from the hybrid vigor (which results when widely divergent strains of an organism are crossbred) and from the fact that the plant's heightened potentials and profits encouraged farmers to apply fertilizers and pesticides.

Hybrids have produced quantum jumps in production in India and Latin America as well, but so far, except in the Sudan, Zimbabwe, and South Africa, they are uncommon in Africa itself. In most of East Africa, for instance, only 5-10 percent of the crop is in the form of hybrids or other improved varieties, and in West Africa the percentage is even lower. This is not unexpected. Occasional U.S. hybrids, such as NK 300, prove productive over a wide range of conditions in Africa, but most do not. Also, most U.S. hybrids were developed for stock-feed and their grains make poor-quality foods. In addition, they lack the necessary resistance to striga, a parasitic plant unknown in most sorghum-growing areas of the United States.

These days, however, hybrids that produce food-quality grain are coming available. Moreover, it would appear that the problems of poor adaptability and striga resistance will be overcome. On the face of it, then, hybrid sorghums produced for sale rather than for subsistence should play a big role in Africa's future agriculture.

Of course, hybrids are not without drawbacks. They perform best under good production conditions and good quality control. They are suited only to sites where seeds and other materials can be readily delivered. (Farmers must purchase fresh seed for each planting.) Further, it has been found in Nigeria that during the rainy season the male-sterile plants used in making the hybrid seed are vulnerable to ergot.[5]

Some observers believe that problems such as these make hybrid sorghum appropriate for only a small part of Africa. This may be true, but as the following sections show, there are reasons for thinking that large-scale, efficient, productive, and very profitable sorghum production can indeed become a major part of Africa's agriculture mix.

[5] This fungal disease infects empty florets. It can be overcome by producing seed under irrigation during the dry season but, at least in West Africa, the areas where this is practical are limited.

Honduran Hybrids

The fact that sorghum hybrids can eventually benefit Africa and other regions is suggested by recent experiences in Central America, where a special kind of hybrid has been developed for peasant farmers.

Farmers in Honduras have in recent decades planted more than 60,000 hectares of sorghum, but harvested less than 1,000 kg of grain per hectare—the lowest yield in Central America. This may not be surprising considering that more than 90 percent is grown on marginal land and the varieties are nondescript landraces (locally called *maicillos criollos*).

These "mixed-breed" strains of unknown ancestry are low yielding, monstrously tall (3-5 m), and late maturing. On face value they should be replaced. However, the farmers resist. As with peasants everywhere, yield is not their top priority. The diverse "mongrels" are preferred because they are dependable. Also, they mature later than maize so that farmers growing the two crops together have time to harvest both conveniently.

But now a big change is beginning. Now researchers have crossbred *maicillos criollos* with elite germplasm from overseas.[6] This has produced new, souped-up forms of the traditional types, called *maicillos mejorados* (improved indigenous varieties) or *maicillos enanos* (dwarf indigenous varieties). They are still basically the dependable, convenient types of old, but the new genes have reduced their height, improved their disease resistance, and increased their yields.

These slightly renovated rustic relicts, still retaining the qualities that farmers value, have broken through the yield plateau that for years strangled greater sorghum production. Improved *maicillos* (the word means "little maize" and reflects the fact that sorghum and maize are not too distantly related) yield 24-58 percent more than their ancestors, even when little or no fertilizer is applied.

A second phase is now beginning. It involves hybrids made by crossing two local landraces. Although hybrid sorghums have been known for four decades, they have previously been made by crossing only elite parents. Honduras is unique in using the local "mongrels" as parents. For purposes of producing the necessary hybrid seed to sell to farmers, researchers there have created dwarf lines that can be mechanically harvested using combines. In trials throughout Honduras the resulting *maicillos* hybrids have outyielded the traditional landraces by 100 percent. Some have produced 6,000 kg per hectare under dryland conditions. The plants are taller than their dwarfed parents

[6] The elite materials were from Texas A&M University and ICRISAT and mainly comprised types developed in the Sorghum Conversion Project. The *maicillos criollos* were collected throughout Honduras, Guatemala, and El Salvador.

(because of complementary height genes), and they can still be used in the traditional maize/sorghum intercropping system.[7]

Unlike other new technologies that tend to benefit the affluent and progressive farmers most,[8] hybrid *maicillos* are targeted for the poor and less venturesome. They provide an alternative that may increase yields on perhaps 235,000 hectares throughout Central America. Cost to the farmer? Negligible, according to the researchers involved. The seed needed to plant a hectare (when cropped with maize) costs no more than a chicken or two, or about a third of the cost of a bag of fertilizer.

"Vybrids"

The criticism most commonly aimed at any hybrid crop proposed for poor farmers is that its seed is worthless for replanting. The fact that farmers must purchase new seed each year is often seen as a disastrous financial burden. Much of the criticism has been overemphasized.[9] However, in many developing countries logistical logjams and supply bottlenecks do make it difficult to produce hybrid seed and get it to the farmers on time and in good condition.[10]

With sorghums, however, there is a distant possibility of having the best of both worlds—to grow hybrids that also produce seed that can be planted. These so-called "viable hybrids" or "vybrids" are not yet available, but a few sorghum researchers are hot on their trail.

Vybrids are made possible by the fact that certain rare sorghums are apomictic—they produce offspring without the male and female gametes fusing. In other words, their seed arises from a nonfertilized nucleus, and for this reason each plant produces progeny genetically identical to itself. This special clonal propagation through seed retains the benefits of hybrid performance while not requiring a highly developed industry to produce and distribute seed each year.

The theoretical possibility of producing viable hybrids in crops was discussed as early as the 1930s. Nearly 60 years later, the various

[7] Information from D.H. Meckenstock.

[8] Although this is a widespread belief, it seems to be true mainly in the initial phase. After a new technology is established, all farmers—even the poorest—eventually benefit. In fact, despite much rhetoric to the contrary, the poor farmers of Asia benefited more from the Green Revolution than the rich ones—they got life itself when the widely predicted famines never materialized.

[9] For example, no hybrid can survive in the marketplace unless its improved performance and the farmer's increased income far outweigh the cost and bother of purchasing seed. Also, experience in India and in Africa is showing that farmers are fully prepared to pay as long as the cost is justified by the hybrid's performance. In addition, it takes very little sorghum seed to plant a hectare. Compared to maize, the cost should be much less.

[10] This, too, is often overemphasized. Hybrid maize is a success in Kenya and Ghana, for example. However, getting good seed to the right place and on time is likely to remain a real constraint in most African nations, at least in the near term.

SORGHUM BEER

In Africa, as in many parts of the world, brewing uses vast amounts of grain. However, in Africa the raw materials are sorghum, maize, pearl millet, and finger millet, not barley, rice, or wheat. Also, the basic process is unique. African brewing includes a lactic-acid fermentation, known as souring. And the resulting beverage is something like a fermenting gruel and has the consistency of malted milk.

Normally called "sorghum beer" or "opaque beer," this drink already constitutes a considerable part of the diet in many areas, and it will likely become an ever bigger commodity. With so many people moving into the cities, it is even now shifting from an exclusively family enterprise to an industrialized one. In South Africa, for instance, sorghum-beer brewing is already a highly specialized industry. Annual production is about one billion liters.

Malting is the first step in brewing this or any type of beer. The grain is soaked and left to germinate. This activates amylases and other enzymes that hydrolyze the grain's starch and proteins to sugars and amino acids. After several days, when germination is complete, the sprouted grains are dried, ground to a coarse powder, mixed with cold water, and added to a preparation of ground-up grain that previously has been steeped in boiling water.* The enzymes continue working, this time turning the new source of starch into sugar. The souring process also takes place as bacteria act on part of the sugars to form lactic acid. The product—a thin gruel called "sweet wort"—may be drunk after less than a day. Its alcoholic content is negligible, but it contains some B vitamins and it is often given to children.

If the brewing is continued, various yeasts multiply, and within a day or so fermentation begins. This produces alcohol, B vitamins, new proteins, and more lactic acid. The resulting brew is normally drunk after 4 or 5 days. Suspended particles of starch, yeast, grain, and malt give it the characteristic milky body. High acidity (resulting from the lactic acid) prevents the growth of pathogenic microorganisms. †

Brewing raises the nutritional value of sorghum. It adds vitamins, neutralizes most of the tannins, hydrolyzes the starch to more digestible forms, and increases the availability of minerals and vitamins. South African studies indicate that iron is 12 times more available in sorghum beer than in a boiled sorghum gruel; riboflavin may be almost twice and thiamine almost a third more available; niacin's availability remains unchanged. In principle, 2 liters of

sorghum beer could supply a person's daily requirement for thiamine and riboflavin and 40 percent of the requirement for niacin. However, many of these B vitamins are locked up in the yeast cells and cannot be digested unless the beer is first boiled. Unfortunately, this is seldom done.

Special varieties of sorghum are maintained for their brewing qualities. In many places, the dark brown grains are prized. Their most important characteristic is their high level of amylase activity. They have considerable potential as substitutes for barley, even for brewing lager-type (European-style) beers. Nigeria already uses them this way, at least on a semi-commercial scale.

Recently in South Africa, the Council for Scientific and Industrial Research (CSIR) developed three shelf-stable brewed-sorghum products: a pasteurized bottled beer, an aseptically packed still beer, and a wort concentrate that can be diluted and fermented to produce beer. These are safe to transport, and can be distributed to remote areas or even exported. ‡

In South Africa, sorghum beer is the basis of a giant company that was formerly part of a government monopoly but has now been spun off to African entrepreneurs with amazing success (see box, page 305).

The beer is more than a mere drink. As one writer has stated: "The whole social system of the people is inextricably linked up with this popular beverage: the first essential in all festivities, the one incentive to labor, the first thought in dispensing hospitality, the favorite tribute of subjects to their chief and almost the only votive offering dedicated to the spirits. Beer is a common means of exchange or payment for services rendered, and in times of plenty it is not only freely consumed, but often is the principal or sole food of many men for days on end. It is evident in all ritual and ceremonial occasions binding together different groups or individuals and affecting a reconciliation when things go wrong. With most tribes, harvest thanksgiving takes the form of beer, preceded by an offering of beer to the ancestors of the chief."

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* Grain for this purpose is usually sorghum or maize, but other grains and even banana are also widely employed. The boiling water gelatinizes the starch, rendering it readily hydrolyzable by the malt amylase enzymes.

† These beers are safer to drink than water because, at consumption, their pH is between 3 and 4, an acidity level at which no common pathogenic microorganisms grow. However, sorghum beer is not immune to spoilage; acetic-acid-producing bacteria (as in wine) can quickly turn it to vinegar.

‡ Information from John R.N. Taylor, Brewing and Beverage Program, CSIR.

attempts at producing them have resulted in some progress. One notable success has been in breeding buffel grass (*Cenchrus ciliaris*)—a native African species, distantly related to sorghum, that is used as a forage throughout the tropics. Another has been with forage grasses of the genus *Dichanthium* (*Bothriochloa*).

Work on sorghum apomixis has now reached the stage where apomicts and vybrids from crosses between them have been formed in research facilities. The scientists are confident that the vybrids can now be developed for farm use.

Vybrids will benefit more than farmers. For sorghum breeders of all stripes, vybrids offer exciting potential. Sexual types can be used in the normal way to develop hybrids with superior characteristics and then induced into apomictic forms that will retain the new qualities, generation after generation, from then on.

STRIGA-RESISTANT TYPES

One of the tragedies facing Africa is that a parasitic plant is cutting it off from the wealth of sorghums that have been, or are being, developed in a score of countries overseas. Indeed, striga is probably the greatest constraint to the production of foreign sorghums in Africa itself.

Recently, however, researchers have discovered a striga-resistant gene in sorghum. This could be a big breakthrough. For Africa, it will help open the door to the truly remarkable types developed in the Americas and China, for instance.

This topic is treated in Appendix A. It is made suddenly more relevant because a new test has been developed that can determine, within a few days, whether a certain sorghum (or other species) is resistant to striga. Tests in laboratories and greenhouses have been most encouraging. Should these results also prove practical in the field, it could open the way for overcoming the depredations of this vegetative parasite that victimizes desperately needed food plants. For the first time the crops will have the means to defend themselves.

DWARFS

The last 40 years have seen dramatic increases in the yields of wheat, rice, maize, and some other cereals. This has come not from boosting the plants' overall growth (as most people may think), but from rearranging their architectures so that the plants are shorter. With less energy going into stalk, more is left for growing grain. In

Sorghum researcher, Gebisa Ejeta, examines experimental plots of strigatolerant cultivar SRN-39 (left) and local cultivars in Niger. The pernicious parasite occurs only among the striga-susceptible local type (right). Striga-tolerance has been known in India and East Africa, but SRN-39 is one of the first examples of a sorghum that can withstand the West African striga species. For more information on striga and the problems it causes, see Appendix A. page 276. (D. Rosenow)

SORGHUM'S MIRACULOUS CONVERSION

At first glance, sorghum seems almost impossibly diverse. Seed banks hold more than 25,000 samples, all distinct and all able to produce fertile intercrosses. How to extract from the myriad combinations the particular ones most useful worldwide is a monumental problem that might seem beyond the realm of reason. However, remarkable progress is already being made, thanks to a project that exemplifies how many of the cereals in this book might be advanced in the future.

In the 1950s, U.S. Department of Agriculture scientist Joseph Stevens developed a "blueprint" for systematically enhancing the genetic base of the world's sorghum crop. Along with several colleagues in the United States and India, he began assembling, evaluating, characterizing, and classifying a base collection of sorghum samples. This collaborative effort was carried out in India and continued into the early 1960s. The Indian government, as well as dozens of African and Asian countries, contributed their germplasm and support. Eventually, about 11,000 different sorghums were on hand.

As a first step in sorting useful genetic materials out of the vast sorghum collection, a unique "shuttle-breeding" procedure was devised. The breeders produced and grew a first generation of random crossbreeds in the tropics (mainly at Mayagüez, Puerto Rico) where the days are short. They collected seeds from a wide range of the most desirable looking progeny and took them to a temperate zone (Texas) where days are long during the growing season. There, the seeds were grown out and a new generation of seeds were gathered again from the most promising specimens. This dual-latitude screening ensured that the resulting seeds (and their subsequent generations) could grow and produce grain under both tropical and temperate conditions.

The next step was to partially refine these genetically diverse populations. Again, a wide array of different specimens were grown and the most desirable selected, this time emphasizing short stature and early maturity. The final result was a cornucopia of various sorghums—all broadly adaptable to various daylengths, all short in stature, and all early maturing. Out of the myriad tall, slow, and sensitive types, suitable only for small farms in the tropics, have come universally useful types for use throughout the world, on any scale.

Although the resulting plants were selected for basic qualities,

they were deliberately kept diverse. Now, that welter of gene types is being fine-tuned to meet the specialized demands of dozens of different localities. Specific characteristics now being "custom-designed" include:

- Resistance to disease (downy mildew, striga, anthracnose, and smuts)
- Resistance to insects (aphids, midges, worms, shootfly, and others)
- Resistance to stressful conditions (drought, heat, soil acidity, and salinity)
- Strong stalks (to stop the plants breaking or falling over in wet soil)
- Nonsenescence (to keep plants green and functional, even under stress)
- Twin-seed (making *both* florets in the grain-producing spikelet fertile)
- Easy threshing
- Erect leaves (to increase the amount of sunlight intercepted)
- Higher yield (more grains of good size in each seedhead)
- Greater root development (to help the plants withstand stresses)
- Faster grain filling (to reduce danger from drought and insects)
- Resistance to weathering (seeds that do not soften)
- Light colors (to make the most widely acceptable food products)
- Increased protein content (more than 10 percent)
- Superior amino-acid balance (high lysine, in particular)
- Improved flavor
- Greater digestibility
- Expanded diversity for food products (notably specialty types for convenience foods)

Materials from the sorghum conversion program are already helping transform this formerly obscure and often scorned grain into a major contributor to world food supplies. Indeed, their seeds have become cornerstones for much of the present rise in sorghum production worldwide.

All in all, the Sorghum Conversion Program has become one of the most successful plant-breeding programs ever; a model of achievement for crop scientists everywhere and with every crop. It provides populations that are reservoirs of genes, rather than a single, highly inbred variety.

technical terms, this is called raising the "harvest index." Thus, 50 years ago wheat had a harvest index of 32 percent; now it can be as much as 48 percent in some cultivars. In other words, almost half of the weight of the plant (above ground) is now grain.

Moreover, reducing the height makes the plants less likely to get top-heavy and blow over in a summer storm. In addition, the squat, strong plants are more able to benefit from fertilizer, which otherwise would make them spindly and top-heavy. And dwarfing not only boosts yields: wherever mechanical harvesting is practiced, short stature means that the seedheads can be efficiently captured by combine harvesters so that larger areas can be planted.

So far, only a few of the world's sorghums have had their architecture refashioned in this way. Nonetheless, an increasing number of short-stalked sorghums that mature at an even height and can be harvested by combine are becoming available. Most have been created in North America. Indeed, all of America's commercial grain types are now dwarfs.

Initially, sorghums in the United States were tall and had a harvest index of 21 or 22 percent (about the same as in the spindly subsistence types now grown in West Africa), but careful selection, followed by intensive breeding, has reduced the internode length. Now the harvest index for many improved types used in the United States, Mexico, and Argentina is 48-52 percent, as high as that of wheat.

Dwarf sorghums have also been created at research stations in Zambia. These local dwarfs, as well as those from overseas, could eventually usher in a new era for the continent.[11]

CONVENIENCE FOODS

As has been noted, commercial sorghum's major problem in Africa is that markets for flour and foods are undeveloped. If this were overcome, a large and healthy trade between a country's own sorghum farmers and its cities could operate to everyone's benefit. Today, ever-increasing numbers of city folk are being weaned onto wheat-flour bread and white rice, and any resulting economic benefits go mostly to farmers and traders a world away. The tragedy is that many of the city dwellers, especially newcomers, are accustomed to sorghum foods and would continue to purchase them if they could.

It is not inconceivable that Africa could produce vast amounts of sorghum flour and sorghum-based processed foods for sale in the cities

[11] Information from S. Carr. Dwarf types have also been introduced in West Africa but, so far at least, have performed poorly.

and towns (see Appendix B). This could result in opportunities for much innovation.

More than 30 years ago, for example, South African researchers developed a precooked sorghum product. They slurried raw sorghum flour with water and passed it through a hot roller that both cooked and dried it. The product proved very palatable and would keep for at least 3 months without deteriorating. Whole milk or skim milk could be used in place of water, producing a tasty flour rich in protein, calcium, and phosphorus. Processing costs reportedly were low.[12]

This is just one of many approaches by which sorghum might be produced for urbanized peoples. Many recipes using milled sorghum grits or flour have already been developed and tested by several universities.[13] And the recent development of parboiled products from sorghum could open up even more markets that could benefit millions of Africa's farmers (see Appendix B).

[12] Coetzee and Perold, 1958.

[13] These include the Home Economics Department at the University of Nairobi and the Department of Soil and Crop Sciences at Texas A&M University (see Research Contacts).

10

Sorghum: Specialty Types

Sorghum's range of genetic diversity is truly amazing. Some types look so abnormal that until recently they were classified as separate species. However, all of them cross readily with one another, all have a chromosome complement of 2n = 20, and all are recognized today as variants of the same plant, *Sorghum bicolor*.[1]

Many of the unusual types are promising resources in their own right. Some have properties and uses quite unexpected of a cereal. A few hold out the possibility of producing far better grains than those of today's major sorghums. Others could provide entirely new types of sorghum foods. Yet others can yield feed, forage, fertilizer, fiber, fuel, sugar, and raw materials for factories of many kinds. In this array of plant types, the vast potential of this remarkable species can be seen. Examples of promising, but little-known, food types are discussed below.

POPPING SORGHUMS

In parts of Africa and Asia, sorghums that pop like popcorn can be found. These have seldom received much scientific or entrepreneurial recognition. There is probably, however, a huge latent market for them. They make tasty foods, and they may have worldwide promise. Popping boosts the flavor of sorghum, and it is energy efficient and nutritionally desirable. (Compared with boiling, for instance, popping is so rapid that it takes little fuel and it denatures or hydrolyzes the proteins and vitamins only slightly.)

Popped sorghum is already a favorite in central India, and it is starting to find favor in several other countries as well. In India, people

[1] Synonyms include *Sorghum vulgare* (for the entire species complex) and *Sorghum caffrorum, Sorghum caudatum, Sorghum conspicuum, Sorghum arundinaceum, Sorghum dochna,* and *Sorghum durra* (for what are now considered subspecies, or "races"). There are hundreds of common names. Those in widespread use include: guinea corn, jowar (India), kaoliang (China), kafir corn, milo (United States), sorgho, and maicillo (Central America).

sprinkle a handful of dry grain onto a bed of hot sand or a hot sheet of metal. The popped kernels are brushed off as they form. Most are consumed by school children as a snack. They may be balled with crude sugar (jaggery). They may also be pounded into a nutty-flavored flour, which is typically mixed with milk and sugar, buttermilk, salt, or chilies.

A world collection of sorghums is maintained at ICRISAT. Of 3,682 accessions tested, 36 have shown good popping qualities. Most originated in India. These could be the starting point for breeding popping sorghums on a scientific basis. Indeed, they could create a new and very tasty food that could quickly establish itself in most of the 30 or more nations that grow sorghum as a staple—not to mention in at least that many more nations that now look on sorghum as "barely fit for cattle."[2]

As with popcorn, the best popping types usually have small grains with a dense, "glassy" (corneous) endosperm that traps steam until the pressure builds to explosive levels.

VEGETABLE SORGHUMS

In certain countries, sorghum is eaten like sweet corn. The whole seedhead (panicle) is harvested while the grain is still soft (dough stage). It is roasted over open coals, and the soft, sweet seeds make a very pleasant food. These strains are found notably in Maharashtra, India. Like sweet corn, they have sugary endosperms containing 30 percent glycogen as well as grains that shrivel when dry. They are a treat for anyone.

This unique method turns sorghum into a vegetable crop—more like broccoli than like barley. It has so far received little or no serious study from scientists, but it could be a powerful way to capitalize on the plant's ability to produce food in sites where most crops fail. The types that perform this way should be collected, compared, and cultivated in trials. The traditional processes by which they are used should be analyzed, as should the nutritional value. Seedheads in the dough stage may have a better-than-expected food value.

VITAMIN-A SORGHUM

In some developing countries a lack of vitamin A in the daily diet blinds many children. However, certain sorghums with yellow grains

[2] Even popcorn was neglected until quite recently. Although it has long been a popular treat in the United States, only in the last 10 years—since microwave ovens made it convenient for the home and office—have modern breeding techniques been applied in force. Sales have since skyrocketed. The increasing popularity of microwave ovens could also boost the use of popping sorghums.

may solve the problem, at least among sorghum-eating societies. The color comes from xanthophyll and from the carotene pigments that are vitamin-A precursors. People eating them have a better-than-normal production of vitamin A.

Yellow sorghums are especially well known in Nigeria but probably can be found elsewhere, too. The carotene levels are typically only a fraction of those normally found in yellow maize. However, because of poverty or locality, sorghum eaters often have no chance to vary their diets. Yellow varieties may be the most practical way to protect their eyesight.

TANNIN-FREE SORGHUMS

Some sorghum types contain invidious ingredients that "lock up" protein and starch so that a person's body cannot fully get at them. Traditionally, these ingredients have been called "tannins," although strictly speaking, this is not an exact term.[3]

Many sorghums, especially those now grown in East Africa, are high in tannins. To a large extent they have been deliberately selected because birds hardly touch them (see Appendix A). These birds include the quelea—a small, rather nondescript weaverbird that has replaced the locust as the most serious pest of small-grain crops in parts of Africa. This voracious seed-eater may well be the most abundant bird species on earth, and its importance as a pest has increased in recent years despite all the control operations that have been mounted against it.[4]

Today, people can eat the dark-seeded sorghums only if the tannins are first removed. There are two approaches for getting around this. One is to use the seeds in processes that neutralize tannins—making beer or fermenting the grain with wood ash are examples.[5] The second relies on the fact that the tannins are located primarily in the grain's outer layer. Milling this off makes the rest of the grain edible. This is not easy to do, however, and the seemingly endless task of pounding seeds with heavy poles causes untold hours of daily drudgery throughout most of rural Africa. Indeed, it is one of the fundamental barriers to the wider use of this crop (see Appendix B).

Overcoming the tannin problem would open new possibilities for

[3] Recent research has shown that the antinutritional ingredients are more than just the pigments known as tannins.

[4] Quelea remains a threat to crops in Zimbabwe, for instance, even though more than 521.5 million of them were killed in the country between 1972 and 1987 (an average of 32.6 million a year).

[5] Information on the wood-ash treatment is from G. Graham, who noticed that campesinos in Peru had developed it as a way to make sorghum more palatable.

sorghum as a world food grain. Research in the 1980s has demonstrated that the genes controlling tannin production can be reduced through crossbreeding. Tannins can be eliminated or at least reduced to negligible quantities. White-seeded, tannin-free types are known and are particularly promising for the future.

BIRD-RESISTANT SORGHUMS

Removing tannins makes sorghum a far better food for humans, but in parts of Africa, unfortunately, it would seem also to be good for the birds. However, some white-seeded types that are both tannin free and shunned by birds are already available.

Two sorghums that are bird resistant and free of tannin were identified in 1989.[6] These two genotypes (Ark 1097 and a Brazilian hybrid) were assayed and found to contain absolutely no tannin throughout the whole time their seeds were developing. In addition, both showed good bird resistance in trials in Indiana, USA. In Puerto Rico, where bird pressure is greater, each was damaged, but only in one of two replications; in the other, it remained untouched. All in all, these white-seeded, tannin-free genotypes appear to be slightly less bird resistant than the standard, strongly resistant, high-tannin types. Nonetheless, the level of resistance was enough that these sorghums can be very useful in areas where bird damage is normally severe.

The nutritional quality of these two is not yet fully determined, but all indications are that both are fully comparable to the low-tannin (bird-susceptible) sorghums. In a feeding trial, for example, laboratory rats grew much faster and showed more efficient feed utilization than the (high-tannin, bird-resistant) control. Remarkably, they were even better than the low-tannin types. Indeed, there were no apparent nutritional problems associated with consuming the grain.

Trials of these sorghums are under way in Kenya.

QUICK-COOKING SORGHUMS

The starches in the grains of most sorghums have gelatinization temperatures around 70°C. They must reach that temperature to become cooked and edible. However, research has shown that some sorghums have starches whose gelatinization temperature is only about 55°C. This can reduce the cooking time required. These sorghums have waxy kernels (endosperm) rather than hard vitreous ones. Thus,

[6] Information in this section from L. Butler.

they cannot always be used in the normal manner. Nonetheless, there is a good possibility that they will make nontraditional quick-cooking products that will appeal to many.

These unusual types are found especially in East Asia. The starch in their grains is entirely amylopectin, rather than amylose and other normal forms.

AROMATIC SORGHUMS

Some sorghums in Sri Lanka and northeastern India are said to have the aroma of basmati, the fragrant rice preferred by millions of Asians. Although bland-tasting rice has dominated international markets, the basmati type has always been tropical Asia's favorite, and it is now increasingly sold worldwide (even in the United States) as a high-priced specialty. The discovery of sorghum counterparts opens up similar opportunities. They, too, might become specialty foods of high value. Also, they might help boost the acceptance of sorghum—normally the blandest of grains—even where it is a staple.

All in all, flavorful types like these present good opportunities for improving markets and increasing consumption, not to mention boosting the returns to farmers.

QUALITY-PROTEIN SORGHUMS

Deep in the misty green valleys of Ethiopia's highlands is hiding a unique sorghum that, in both nutrition and palatability, far surpasses the thousands of types found elsewhere.

Ethiopians call these types "milk in my mouth" (*wetet begunche*) and "honey squirts out of it" (*marchuke*). To anyone who has tasted normal, bland, sorghum flour, the names alone indicate something special. Both varieties produce somewhat lower yields than normal but everyone likes to eat them. The taste of roasted *marchuke,* for instance, has been likened to that of roasted chestnuts. People gather the grains, roast them over a fire, and pop them down like peanuts. Both are often used to enhance the flavor of local dishes made from regular sorghums. The taste comes from the reducing sugars that caramelize as they are roasted.

Until 1973 these two varieties were restricted to a tiny upland area of north-central Ethiopia. The growers hid them in the middle of their sorghum fields (mainly so the landlords wouldn't find out and raise the rents based on the extra income from these elite types). In 1973, however, researchers analyzing different sorghums for their food value

stumbled onto them.[7] Of 9,000 varieties tested, these two were unique. They contained 30 percent more protein, but more important, their protein had about twice the normal level of lysine, an amino acid critical to nutritional quality.

This finding is significant because the more than 500 million people for whom sorghum is the main source of sustenance are relying on a food that is not great, nutritionally speaking. Its protein content is modest (averaging about 9 percent), and its protein quality is among the lowest of any cereal—mainly owing to its dismal lysine level.

In the years since 1973, neither of the two quality-protein sorghums has fulfilled its promise. There are several reasons for this. Both types produce floury grains with small and soft endosperms, a feature that makes them more susceptible to birds, fungi, and insects. More important, however, soft grains are not favored for traditional purposes. Upon pounding or milling in a machine, they form a paste rather than a flour. Also, there is not much endosperm there to make a flour from in the first place.

This fundamental problem with grain type is a big barrier: either a laborious breeding program is needed to transform the grains into the hard-endosperm form[8] or people must use the soft form in foods differing from their normal grain-sorghum fare.

A promising immediate use of these remarkable varieties is as feed. Animals are less fussy than humans, and lysine-rich feeds, which are particularly necessary for pigs, are critically short in many places. Fish meal and soybean meal (the main lysine sources for livestock) are often unavailable or too expensive, especially in remote Third World areas. High-lysine sorghum with its inbuilt robustness and drought tolerance could well become a vital feedstuff for northern China; large, dry areas of the Soviet Union; much of the Middle East; the semiarid zones of India and Pakistan; substantial portions of Mexico; and other places that are dry, salty, and lacking in lysine-rich feeds.

Moreover, the single gene responsible for the high lysine may be invaluable for boosting the quality of conventional sorghums. Researchers at several research facilities are trying to transfer this gene. They hope to enhance the nutritional value of normal sorghums without affecting the grain structure or other important traits.

SORGHOS

Sorghum and sugarcane are fairly closely related, and certain sorghums (often termed "sorghos") have stems that are just as rich in

[7] The researchers were John Axtell and Rameshwar Singh of Purdue University.

[8] This has been done with a high-lysine maize (see the companion report, *Quality Protein Maize).*

THE SUPER SORGHUM OF THE SUDAN

Although it is perhaps the most important grain in Africa, sorghum still has tremendous untapped potential. Many remarkable types are yet to be discovered by science, as the following example shows.

When word leaked out in 1984 that a disastrous famine was impending in Dafur and Kordofan, the horror that swept the world energized many people into action. No one took a more original approach than the organizers of "Band Aid," a project in which rock and roll stars staged a free concert for worldwide television. The donations from dozens of countries then went to help those stricken provinces of the Sudan. Part ended up in a far-sighted study of sorghum.

With Band Aid funding, David Harper, Omar Salih, and Abdelazim Nour visited 150 villages in the drought-devastated area, checking on the people's welfare and gathering samples of the local crops—especially those that had best survived the drought. A sorghum variety called "Karamaka" proved to be truly remarkable.

For one thing, Karamaka had a protein that was unusually nutritious. It had more than the normal amount of protein but, more importantly, its protein had about twice the nutritional value of other sorghum proteins. Its lysine content (3.4 percent) was 62 percent above normal, and the other essential amino acids were not diminished to any significant extent. As a result, Karamaka protein had a chemical score of 62 rather than the 30-40 figure of regular sorghum protein. Its nutritional value was therefore almost two-thirds that of milk protein, the usual standard of protein perfection.

For another, Karamaka grain possessed an unusual combination of carbohydrates, containing less starch and much more sugar than normal. Indeed, the total sugars in the grain amounted to 35 percent. The individual sugars were composed of both sucrose and reducing sugars, but the sucrose level alone was approximately twice normal.

The ultimate star of the Band Aid concerts may be this drought-tolerant crop, whose palatability and protein might lead sorghum into a new era of significance for feeding the world at large. Karamaka not only foiled the famine, it proved a nutritional gem, on a par with the best quality cereals.*

* More information is available from D. Harper (see Research Contacts).

sugar as sugarcane's. These sweet sorghums are surprisingly poorly known compared with sugarcane and sugar beet. Nonetheless, they have a big potential in a world increasingly in need of renewable sources of energy (see next chapter). Also, as food crops they deserve more attention.

Unlike sugarcane, sweet sorghum grows in a wide geographic range. It can be considered "the sugarcane of the drier and temperate zones." It has a production capacity equal or superior to sugarcane's, at least when considered on a monthly basis.

Two types have been developed by breeders:

- Syrup sorghums, which contain enough fructose to prevent crystallization; and
- Sugar sorghums, which contain mostly sucrose and crystallize readily.

RICELIKE SORGHUMS

The *shallu* type of sorghum (the margaritifera subrace of the guinea race) has small, white, vitreous seeds, which are boiled like rice.[9] As of today, little or nothing is known about this interesting form of sorghum, but it could have a good future and deserves exploratory research.

TRANSPLANT SORGHUMS10

In certain regions of semiarid West Africa, various special sorghums are transplanted like rice. These are used particularly by peoples living in the bend of the Niger, including parts of Cameroon, Chad, Niger, and Nigeria.

Little is known about these. However, transplant sorghums are produced in the dry season—growing and maturing entirely on subsoil moisture. They are ephemerals that must get through their life cycle before the soil dries back to powder or pavement. They must mature quickly to survive. Some can produce a crop in 90 days—merely half the time the rainfed types require in that area.

One fascinating example has been identified at Gao in northern Mali. It is cultivated by ex-nomad Tuareg, and yields more than 1,000 kg per hectare on residual moisture from the runoff water remaining after light rains.[11] Two others are masakwa and moskwaris.

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[9] Information from J. Harlan.

[10] Information largely from R.K. Vogler.

[11] Information from J. DeVries.

These dry-season sorghums have special traits including:

- Large, hard, high-quality grains, locally considered special delicacies;
- Heat tolerance at the seedling stage;
- Drought resistance or tolerance; and
- Ability to flourish on residual moisture in heavy clay soil.

Transplant sorghums grow only on clay pans with a high water table. They are often cultivated on vertisols, which are among the world's most refractory and frustrating soils to deal with. Wet, these soils become soft, sticky, and plastic; dry, they become iron hard and deeply cracked. At least once a year they go from one extreme to the other. Few plants can withstand the trauma. For all that, however, vertisols have high fertility. Any crop that can perform in such recalcitrant sites could be a boon to several parts of the tropics that are now languishing for lack of a crop suited to vertisols. Transplant sorghums therefore deserve international attention.

The yields from transplant sorghums depend on the amount of moisture stored in the soil, but are relatively high by the standards of the very difficult sites where they are grown. (Their high yields probably result from the fertility of the swamp clays.)

These transplant types apparently are uniquely adapted to the unusual conditions of inundated clays and perhaps are unsuited to dry or infertile soils.

FREE-THRESHING SORGHUMS

Despite general opinion, some sorghums thresh easily. The heads hold onto the seeds during the harvest as well as during drying and transport; however, the farmer can separate the seeds from the heads with hardly more effort than is used to thresh wheat or rice. For example, the sorghum variety called "Rio" has an "easy thresh" characteristic. Another variety line being used currently in U.S. breeding programs is SC599. It is both free threshing and tolerant of drought in the post-flowering stage.[12]

The term "free threshing" is also applied to the involute glumes of some West African guinea sorghums. Their seeds are completely exposed and they easily thresh completely free of the glumes.

[12] Information from F.R. Miller. The glumes (chaffy bracts) in these free-threshing types cover about 30 percent of the seed.

SORGHUM COMES TO AMERICA

Sorghum has been in the United States for a long time. The grain types commonly called "guinea corn" and "chicken corn" were introduced from West Africa at least two centuries ago. Both were probably packed as provisions on slave ships and reached the New World only inadvertently. Americans first grew these grains along the Atlantic coast but later took the crop westward where it found a better home in the drier regions. Later-arriving grain types include some that were deliberately introduced by seedsmen and scientists towards the end of the 1800s. By 1900, sorghum grain was well established in the southern Great Plains and in California; indeed, it had become an important resource in areas too hot and too droughty for maize (see page 160).

The sorghum known as "broomcorn" was supposedly first cultivated in the United States by Benjamin Franklin. He is said to have started the industry in 1797 with seeds he picked off an imported broom. The stiff bristles that rise from the plant's flower head have produced many of America's brooms and brushes ever since (see page 209). By the 1930s, for example, American farmers were cultivating 160,000 hectares of broomcorn.

The so-called "sweet" sorghum, with its sugar-filled stems, reached these shores in about the mid-1800s. It landed first in the Southern states —supposedly introduced as a cheap treat for slaves. Within 50 years, however, it had spread so widely and become so popular that sorghum was known as "the sugar of the South." Each locality in the Southern farm belt had a mill to crush sorghum stalks. The resulting syrup, a little thinner than molasses, became *the* sweetener of the region: poured over pancakes, added to cakes, and everywhere employed in candies and preserves. Today, this golden liquid is not so well known, but many rural communities still hold annual sorghum festivals and crude old mills squeeze out an estimated 120 million liters of syrup each year.

Sudangrass was introduced in 1909. This form of "grass sorghum" is now used for animal feed throughout the nation's warmer regions (see page 211).

A scene in the backhills of North Carolina. Sugar sorghum has all but disappeared from commercial cultivation in the United States, but it is still grown on a small scale, mostly for home use. The thin greenish liquid squeezed out of the stalks is boiled down into sorghum molasses, thinner in consistency than sugarcane molasses, but lighter in color —an almost transparent golden shade. (P. Mask)

SORGHUM IN CHINA

In China, sorghum is amazingly popular. In the northern parts, especially, millions of villagers consider *kaoliang* a part of everyday living. Many employ every part of the plant—from top to bottom.

Grains. For millions of Chinese, sorghum is a daily staple. The grains are eaten at perhaps every meal. Certain types of waxy grains are baked into cakes. Other types are fermented and distilled into strong spirits. To connoisseurs, China's best liquors are those made from sorghum—the famous (or infamous) *maotai* and *samshu,* for example. Certain grains, particularly the darker-colored varieties, are vital for feeding horses, donkeys, and other livestock.

Seedheads. In some varieties, the empty heads are converted into brooms and brushes.

Stalks. Sweet-stemmed sorghums are a major source of sugar to millions of Chinese. Some are also harvested green and cut up like sugarcane batons. (Children are particularly fond of chewing on them.) The stalks of more woody varieties are bound together, cemented with clay, and used for partitions and walls and fences. The supple green stems are split and woven into baskets and fine matting. The strong dry stems are widely used in making handicrafts and many types of small household utensils, including plate-holders and pot covers. Sorghum stalk is, moreover, a favorite for making children's toys and many types of containers. (Sorghum cages are used to keep pet birds and insects, for example.) In some places, woody sorghum stems are the basic fuel for cooking.

Leaves. In parts of China the leaves are frequently removed before the grain harvest and used for fodder. They are vital for raising cattle, goats, horses, and rabbits.

Roots. The roots are grubbed out and dried for fuel.

All this is not just an ancient traditional practice. In modern China, hybrid sorghum has played a vital role in increasing food supplies. These days, sorghum is a high-yield crop—both for grains and for stems. In sum, the experiences in China demonstrate just how universally valuable this African grain can become.

CHINESE SORGHUMS

All sorghums are indigenous to Africa, but the plant reached Asia so long ago that thousands of cultivars developed there. Indeed, the Far East devotes a huge area to this crop. It is especially surprising to find this tropical crop in chilly climes as far north as Manchuria. Throughout northern China, however, farmers rely on sorghum not only to keep themselves fed when wheat fails but also for many of their household needs (see box opposite). Even when wheat is available, the people often eat a cheap and rather coarse sorghum bread. Special steamed breads are made from sorghum in some areas. Sorghum also goes into noodles, porridges, and boiled (ricelike) dishes. A significant proportion is used to produce strong liquor. Sorghum is also eaten, although to a lesser extent, in Japan.

China contains a cornucopia of types that are unknown elsewhere. *The Flora of Chinese Sorghum Varieties,* for example, lists more than 1,000 local varieties: 980 for food, 50 for industrial use, and 14 for sugar. All of these should be rapidly gathered and tested elsewhere in the world. They undoubtedly offer many genetic benefits. Eventually, they and their genes may become critical to human survival in many areas outside China.

Reuniting the genes of these Far Eastern types with those of Africa after a 2,000-year separation could be an extremely powerful genetic intervention leading to a whole new line of "Chinaf" hybrids.

COLD-TOLERANT SORGHUM

When CIMMYT first tried growing sorghum in the Valley of Mexico, the crop would not set seed. The problem was low temperatures at night. The researchers then got some high-elevation sorghums from Ethiopia, made crosses, and now have types adapted for that upland valley with its chilly nights. Cold tolerance is available in the germplasm but has not yet been fully exploited.

HEAT-SHOCK SORGHUM

Sorghum thrives under searing conditions. Air temperatures of 45°C leave it unfazed. Even at that temperature, young plants have been known to grow 20 percent in height in a single day. But sorghum has its limits. When soil temperatures climb above 50°C, its seedlings struggle to survive. Such temperatures are not uncommon at the soil surface in semiarid areas, and the consequences for sorghum farmers are often dire, sometimes even disastrous.

Now, researchers at ICRISAT have found that certain sorghums withstand heat better than others. No one has paid attention to this quality before, and almost all of today's sorghums produce seedlings susceptible to burning hot soils.

By sowing seed in hot fields and seeing which survived, lines with heat-tolerant seedlings have been identified. But such tests are expensive, time-consuming, and subject to hosts of uncertainties. Now, researchers at the Welsh Plant Breeding Station[13] are devising mass-screening techniques that can be performed in a laboratory and with much more precision.

One Welsh technique, already adopted by ICRISAT, monitors the amount of protein synthesized by the germinating seeds. In hot surroundings, the most heat-tolerant types produce the most protein. However, this test is expensive and cumbersome to run on thousands of samples, so now the Welsh researchers are developing a second-generation test based on "heat-shock proteins" (HSPs).

All living things make HSPs when exposed to temperatures above their normal range. They do it quickly—often within 15 minutes. Once made, the proteins—which are similar in plants, animals, and bacteria—seem to confer an ability to prosper in the heat. Their exact function is still uncertain, but they may protect the organism's proteins, messenger RNA, or membranes from damage. One HSP—often called HSP70 because it has a relative molecular mass of 70,000—may ensure that heat-damaged proteins regain their proper shape so that they can continue working as enzymes, muscles, and antibodies.

The researchers now have found that briefly exposing a sorghum seedling to temperatures between 40°C and 45°C induces it to produce a characteristic set of HSPs. From then on, the plant can tolerate temperatures of 50°C or even more without suffering damage.

Although all sorghum seedlings make HSPs, those that tolerate heat best make HSPs much sooner after germinating. Speed is the secret of their success.

This response is being studied in the hope of finding an easily recognizable feature that can identify heat tolerance without torturing the seeds. If successful, this will open the way to mass screening so that farmers in the hottest areas will no longer face the heartbreak of seeing their fields wilting in the blazing sun before the plants have even grown more than knee-high.

Another approach is to find the regions of the chromosomes which are important for survival of heat stress. DNA probes are being used as markers by the researchers in Wales to follow regions of the chromosomes linked to the thermotolerance trait from parents to subsequent generations.

[13] Led by Cathy Howarth and Chris Pollock.

TROPICAL SORGHUMS

A few sorghums grow in the humid lowland tropics. Although they are not well studied, the guineense and other related groups (roxburghii and conspicuum, for example) could be useful as genetic sources for improvement of genotypes for humid tropical regions.

WILD SORGHUMS

At least two undomesticated forms show extremely robust growth under the harshest of conditions.

One, the verticiliflorum form (previously known as *Sorghum verticiliflorum)* is a wild grass, distributed from the Sudan to South Africa. It is often found in damp areas (along stream banks and irrigation ditches, for example) or as a weed in cultivated fields. On the other hand, it is also a dominant climax species in many of the area's dry, tall-grass savannas. It is thought to be a progenitor of the modern bicolor, caudatum, and kafir races of sorghum but has seldom been considered a genetic resource in its own right. Nonetheless, in research now under way, this plant is proving extremely useful in forage-breeding programs. No doubt it contains disease-fighting abilities and pest resistances that could be deployed to help sorghum.

The other (previously known as *Sorghum arundinaceum)* is a wild and weedy rainforest species that flourishes in Africa's wet tropics, where today's domesticated sorghums are poorly adapted. Although very little information is available, it appears to be more photosynthetically efficient at low light intensities than cultivated sorghum.[14] As of now it is not cultivated, but it may have a future as a domesticated crop for humid and forested regions. It is a robust species, very common along roadsides, vacant lots in cities, and other "wastelands."

WIDE CROSSES

Sorghum can be crossed with grasses genetically distant enough to be classified in different genera or even in different subfamilies. It is certainly highly speculative to think that these crosses might have any economic merit, but exploratory research efforts seem well worth undertaking. A few possibilities are discussed here.

Crosses between sorghum and certain types of *Chrysopogon, Vetiveria,* and *Parasorghum* are possible. Crosses with *Pseudosorghum*

[14] Downes, 1971.

WILL SORGHUM GO HIGH-TECH?

Since the 1960s, when tissue culture was developed for replicating plants such as potato and tobacco on a mass scale, researchers have attempted to apply this technique to grasses. For a decade or two it was considered an impossibility, but recent discoveries have changed that, and a few grasses can now be propagated this way. In 1989, for example, Indian researchers L. George and S. Eapen of the Bhaba Atomic Research Centre in Bombay reported replicating certain cultivars of sorghum using tissue culture. This development could open a new world of understanding and advancement for the world's fifth major food crop.*

The Indian scientists studied seven sorghum cultivars (C021, C022, C023, C024, TNS24, TNS25, and TNS30). Cells from the stems refused to form callus (the first step in the tissue-culture process), but cells from the base of the leaves formed callus in every case. Also, cells from the seeds of one cultivar (C023) formed callus in about one-third of the samples.

When the researchers added hormones to induce the undifferentiated callus tissues to produce plantlets, all the callus samples formed roots. However, only three of the cultivars (C023, TNS24, and TNS25) formed shoots, and then only in 10-15 percent of the samples.

This discovery, while limited, is one upon which further refinements and higher efficiencies can be built. With tissue culture, powerful techniques such as restriction fragmentation length polymorphisms (RFLPs, see page 34), the production of pathogen-free plants, and challenge breeding can be applied to understanding and improving this crop, which is so vital to Africa and the world.

Techniques like these could open possibilities even for far-out developments such as introducing into sorghum the gluten genes from wheat, adding virus-resistance genes, making somaclonal selections, and sorting through the crop's massive genetic diversity in ways that are far more efficient than any imaginable even just a few years ago.

* These results are reported in *Current Science* (India) 58(6):308-310. The researchers used the standard Murashige and Skoog medium to grow the leaf cells and added 2,4-D as a hormone to stimulate growth. They used a combination of kinetin and tri-iodobenzoic acid to induce root growth.

and selected members of the Bothriochloeae and the Sorgheae also seem possible. Crosses between subtribes might be possible if certain members of *Chrysopogon* and *Capillipedium* were used.[15]

American researchers are currently performing experimental crosses between sorghum and johnsongrass *(Sorghum halepense),* a perennial forage that has already introgressed with sorghum to become a pernicious weed in the United States. It is hoped the grain qualities of sorghum can be united with the rhizomatous habit of johnsongrass to create a powerful new perennial cereal.

Recently, crosses between sorghum itself and its sudangrass subspecies *(Sorghum bicolor* subspecies *sudanense)* have produced hybrid grasses with outstanding vigor. Their productivity and performance have boosted even more the acreage and overall yield of forage sorghum, a main part of the livestock-grazing industries of America and Argentina. They also promise to help in reclaiming salt-affected lands (see next chapter).

It has long been known that sorghum can be crossed with sugarcane. Chinese researchers now report developing a hybrid between the two that contains more sugar and produces more stalk and grain than either parent.[16] Research along these lines might turn up fascinating new resources of undreamed-of usefulness.

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[15] These speculations were put forward decades ago by Robert P. Celarier, who was thinking in terms of clarifying taxonomic relationships in the subtribe Sorgheae. However, the economic potential of these man-made crosses might be substantial.

[16] S. Wittwer, Y. Yu, H. Sun, and L. Wang. 1987. *Feeding a Billion.* Michigan State University Press. Such a cross might prove a method for boosting sorghum's grain yield. In a sorghum flower, only one spikelet of each pair is fertile. In sugarcane and its relatives, both spikelets of a pair are fertile. Moreover, this trait can be transferred to sorghum, at least at the tetraploid level. See Gupta et al., 1978.

11

Sorghum: Fuel and Utility Types

Few people heretofore have paid much attention to the idea of growing sorghum to burn. Cereal scientists, quite naturally, have regarded the plant exclusively as a food. But these days, feeding the fire can be as hard as feeding the people. Certain sorghums might help, and they warrant research.

Moreover, fuel is fundamental to many other parts of modern living. Indeed, most of the human race is so hooked on flammable liquids for running factories and powering trains, trucks, cars, and buses—not to mention providing electricity—that life would be impossible, or at least intolerable, without them.

For all that, however, the prime liquid fuel, crude petroleum oil, is in jeopardy. Perhaps the greatest challenge of the coming century will be the development of sustainable alternatives. Surprisingly, sorghum might be one of them. Indeed, sorghum could well bring many countries a giant step toward the renewable-energy future everyone is hoping will eventuate to keep life livable in the post-petroleum era.

This chapter highlights sorghum's potential to produce both solid fuels and liquid fuels, to yield industrial products, and to help maintain the overall sustainability of agricultural production.

FIREWOOD

Although food is fundamental, fuel is almost as basic to the modern diet. Without it food cannot be cooked, and today's main grains, pulses, roots, and tubers, as well as many vegetables, must be cooked to be edible.

These days, millions cook over open fires. Indeed, for more than a third of the world's people, the real energy crisis is a frantic scramble for firewood. In the poorest countries, up to 90 percent of the population depend on wood to cook their meals. In parts of Africa and Southeast Asia, an average user may burn well over a ton a year.[1]

[1] See companion report *Firewood Crops: Shub and Tree Species for Energy Production.* For a list of BOSTID) publications, see page 377.

Although the search for food soaks up a major part of the daily lives of billions, the search for fuel to cook it with is becoming equally time-consuming. Firewood is more and more difficult to find. In an increasing number of places, gathering fuel now takes more time than growing food. There is a saying in Africa that it costs more to heat the pot than to fill it.

Although in recent years much effort has been expended on developing firewood crops, few advisers or administrators have ever thought of developing sorghum for the fire. It is a fact, however, that certain types have woody stems that put out surprising amounts of heat. They could well become part of the mix of the firewood crops of the future.

Although these solid-stemmed sorghums have received almost no study as fuel resources, one type has been tested in a preliminary way. It comes from Egypt, where its stalks are more valued than its grains. Egyptians use them as fuel. Called Giza 114, it has solid lignified stalks that burn at an especially high temperature for the stem of a grass.

Little is known about Giza sorghum but, based on results from preliminary trials, it could have a glowing future. It has shown promise in Peru, for example, where it was produced to fuel cookstoves and brick kilns. It is now being tested in Haiti, where it also seems to have good potential as fuel.[2]

It is not inconceivable that sorghums like this could become a standard part of farming in fuel-short nations. Their annual biomass yield is likely to equal or better that from trees. The yield of sorghum stalks has been measured in China as 75 tons per hectare, probably representing more than 10 tons per hectare of dry biomass. This would be a respectable annual production for even the fastest growing trees. The overall yield in fuel-calories per hectare may also be comparable, although even the densest sorghum stem will not equal the caloric output of a wood sample of equal volume. Perhaps, too, a modest harvest of grain can also be achieved.

Compared with trees, sorghums have the advantage in that they produce fuel within months—even weeks, Several crops a year may be possible in appropriate locations. This may help relieve not only the frenzied foraging for firewood that goes on today, but also the destruction of woodlands and forests that seems to end only when desert or degraded soils remain. People who can find fuel in fields close at hand will not hike to far-off forests and haul bulky wood all the way back. Their need is not for large-diameter tree trunks but for small stems that can be easily cut, carried, and fed into the space beneath a pot perched on rocks. For such a purpose, solid-stalked sorghums could become vital resources of the future.

[2] Information from M. Price.

Sorghum stalks make a poor fuel, but for millions they are all that is available. To this extent, they provide a vital contribution toward relieving hunger because all the starchy staples must be cooked to become edible. (Nathan Benn)

LIQUID FUELS

For the economic stability and expansion of nations, liquid petroleum fuels —kerosene, gasoline, and diesel, for instance—have become essential. As noted, these liquids not only power factories, trains, trucks, and buses, they also generate electricity and produce thousands of items from machines to medicines. Moreover, maintaining mobility is critical to the public welfare: police, fire fighters, ambulances, mass transit, and construction fleets all depend on liquids that will explode in the cylinders of internal combustion engines.

For these and other reasons, the growing dilemma over future petroleum supplies makes it imperative to investigate renewable fuels, especially those suited for use in existing engine types. Of all the nonpetroleum possibilities, ethanol is the only one now significantly used in motor transport.[3]

At present, ethanol is made from either sugarcane or maize. In the future, however, sorghum is likely to also be a prime supplier. The stalks of certain sorghums are just as packed with sugar as are sugarcane's. Their juice contains 13-20 percent total fermentable sugars. They can yield about 6 percent alcohol.

Sweet-stalk types are sparingly distributed across sorghum-growing areas of Africa and India, where people chew the green and tender stems like sugarcane or make syrups, molasses, sugar, or confections from them. They were once a major source of sweeteners in the southern United States. Now, however, they have a rising potential as sources of fuel.

All in all, sweet sorghums are important for future ethanol production because they have:

- High biomass yield;
- High percentage of fermentable sugars;
- High percentage of combustible materials (for fueling the processing);
- Comparatively short growth period;
- Tolerance to drought stress; and
- Relatively low fertilizer requirement.

Moreover, sweet sorghums may produce some grain for food or feed. Indeed, as sorghum is one of the most efficient plants, and as it produces fermentable sugars as well as grain, it seems almost ideal for

[3] See companion report, *Alcohol Fuels: Options for Developing Countries.* National Research Council, Washington, D.C. 1983. Research on another renewable-energy alternative, vegetable oils, is described in E. Griffin Shay. Diesel fuel from vegetable oils: status and opportunities. *Biomass and Bioenergy.* Vol. 4, No. 4, 1993. pp. 227-242.

producing both energy and food. Technologies used in the sugarcane industry can be applied virtually without modification.

Sweet sorghum has a number of potential advantages over sugarcane. For example, it is adapted to many growing conditions, unlike sugarcane, which is restricted to tropical climates. It requires less water and fertilizer. It can be planted more easily (from seeds not stems). And it also has a potential for low unit costs because it can be fully mechanized and the fields need not be burned (unlike sugarcane fields).

Sorghum's advantage over maize (in which the grain is converted to alcohol) is that it produces sugar rather than starch. As a result, sorghum juice can be directly fermented without the expense or delay of an initial hydrolysis.

Recently, researchers in at least three countries have begun to appreciate the potential of sorghum as a fuel as the following examples show.

India

In southern India, the potential of sorghum varieties that yield both grain and sugar-filled stems is being explored.[4] Engineers at the Nimbkar Agricultural Research Institute (NARI) have found that these dual-purpose varieties solve three problems: they yield food, the fuel to cook it with, and the fodder to feed the farm animals that help produce it. From the top of the plant comes grain for food; from the stalk comes sugar (and hence alcohol) for fuel; and from the pulp remaining after the sugar is extracted comes animal fodder.

In the past, multipurpose sorghums were dismissed or at least overlooked, probably in the expectation that the individual yields of the various products would be low. But the NARI researchers are showing that this may not be the case. Indeed, they claim that I hectare of their sorghums can annually yield 2-4 tons of grain, 2,000—4,000 liters of alcohol, and enough crushed stalk to feed from three to five cattle year-round.[5]

The idea of "growing" fuel alcohol is of course not new. However, most other programs have faltered because the cost of the fuel needed to distill the alcohol rendered them economically unattractive. NARI engineers circumvented this by designing a solar-powered still, incorporating a solar collector and a distillation column that can run at 5070°C—temperatures that the solar collector can easily provide.[6] Also,

[4] Rajvanshi et al., 1989.

[5] For the fermentation, NARI uses strains of *Saccharomyces cerevisiae.* The average fermentation efficiency was 90 percent and the fermentation process took 48-72 hours to complete.

[6] The pilot model consists of flat-plate solar collectors (38 m^2 in area) coupled to a hot water storage tank (2,150 1 capacity).

they have developed pressurized and unpressurized lanterns as well as a wickless stove that will run on aqueous alcohol taken directly from the still.

NARI suggests that this combination of multipurpose sorghum and appropriate technology could, in theory, meet all the automotive fuel requirements in India by the year 2000, completely replace the kerosene now used in Maharashtra, and supply 80 percent of the fodder for all the cattle in Maharashtra. Although such levels will never be approached in practice and it seems axiomatic that grain yields will tumble when sugar is also produced, the NARI concept is a powerful one that could be a big breakthrough that boosts sorghum into an energy resource worldwide. And perhaps, after all, it is not too far-fetched to envisage sorghum producing both high contents of sugar in the stem and high yields of grain.[7]

United States

A large sorghum-for-alcohol project was carried out across the United States between 1978 and 1984. As part of this project, the University of Nebraska developed a demonstration farm based entirely on renewable fuels. Sweet sorghum was the principal crop for alcohol production. Hybrids that grew rapidly and produced large amounts of sugar were created.[8]

A major constraint of sweet sorghum in the temperate zone is the harvest period. Wherever the potential of a freeze exists, the harvest period is greatly reduced because the crop must be gathered before any freezing weather. Sugar in the damaged stalks begins to ferment.

Brazil

Of all the nations in the world, Brazil is the ethanol-fuel pioneer. It already has fuel alcohol in large-scale nationwide use. So far, however, this has come almost entirely from sugarcane. Now, Brazil's scientists are exploring the use of sweet sorghum. The two crops, it has been found, supplement one another: sorghum can provide alcohol during the season in which sugarcane is unavailable.[9] Therefore, using the two together increases the period of production, decreases the unit cost, and increases the total amount of alcohol that a distillery can

[7] Researchers in Texas have also discovered that high yields of sugar are not incompatible with high yields for grain. Information from F.R. Miller.

[8] Information from M.D. Clegg.

[9] Sugarcane in Brazil is normally ready to harvest between June and November; the harvesting period for sweet sorghum is from February to May. Information from R.E. Schaffert.

produce each year. The same equipment is used to process both sugarcane stalks and sweet-sorghum stalks.

WILL BRAZIL'S CARS RUN ON SORGHUM?

Brazil leads the world in the use of fuel alcohol. In 1993, about 4.3 million vehicles—one-third of the country's total fleet and about 40 percent of its car population—operate on ethanol. Almost all that alcohol now comes from sugarcane, but in the future it may come from sorghum as well.

Brazilian researchers have shown that sweet sorghum can yield from 22 to 45 tons of raw biomass per hectare in 110 days. Fermentable solids (80 percent sugars and 20 percent starch) in the stalks amount to 2.5-5 tons per hectare. To optimize the output, enzymes are added so that the starch in the stems is also converted to alcohol. Research has shown that in this way 1 ton of sweet-sorghum stalks has the potential to yield 74 liters of 200-proof alcohol.

Such discoveries have implications for countries everywhere. In that distant but inevitable day when the world's petroleum runs out, maybe people will turn to sorghum to keep civilization humming. Brazil is showing us yet another way this remarkable plant will be important in our future.

The Brazilian scientists are also extending their studies to incorporate sorghum into an integrated system in which the by-products are used as food, feed, fertilizer, and fiber. Further, they are adapting this technology to a microscale to allow the economical production of fuel in a decentralized industry. This reduces transportation costs and may perhaps allow the farmers to generate their own energy.

SORGHUM IN SUPPORTING ROLES

Around the world, sorghum is mostly grown for food or feed and (as just mentioned) a little is being grown for fuel. However, there are several interesting uses in which sorghum is grown not for its own sake but for the benefit of other crops. Below are three examples.

Soil Reclamation

Saline Soils

It has recently been found that crosses between sorghum and sudangrass (a special race of sorghum), have the capacity to repair saline soils made crusty by sodium compounds. David L. Carter, director of soil and water management research at the U.S. Department

of Agriculture station in Kimberly, Idaho, predicts that "they are going to produce some good forage on these marginal lands and at the same time will reclaim some of these soils for crops for human consumption."

Acids released by the sordan roots dissolve calcium carbonate or lime, and in so doing they release calcium. The calcium then displaces sodium in the soil. The newly released sodium reacts with carbon dioxide to form sodium bicarbonate, a soluble salt that is less injurious to plants and mostly washes away in the rain.

After growing sordan on sodic lands for about 2 years, farmers can often re-use the soil for conventional crops.[10]

Reclaiming Toxic Soils

U.S. Department of Agriculture scientists in Lincoln, Nebraska, have found that sorghum has an exceptional ability to absorb pollutants out of soil. According to their research, sorghum strips excess nitrogen out of soils with such efficiency that it may solve waste disposal problems for cities and livestock operations (such as feedlots) that generate nitrogen-laden wastes. "We've been able to capitalize on sorghum's natural ability to act as a scavenger," says Kenneth J. Moore. "Sorghum thrives in toxic soils that kill less resilient plants and its penetrating roots can capture the nitrogen in a vast volume of soil."

Moore, an agronomist, and his colleague Jeffrey F. Pedersen, a plant geneticist, are now developing a system in which nitrogen is not only removed but is returned to use safely and economically. They plant sorghum in highly contaminated soils, cut the crop several times through the growing season, and feed the foliage to livestock. The key to the process is sorghum's robust growth and extensive root system.

Such an environmental tool could be very valuable these days. In Nebraska, for instance, municipal and livestock wastes are commonly disposed of by applying them to fallow cropland. An excessive buildup of nitrogen is one of the resulting hazards. "By planting forage sorghum in well-managed cropping system, producers can safely recycle that nitrogen," says Moore.

Two years ago, Moore and Pedersen began their project at a sewage sludge disposal site by planting several types of sorghum: grain types, forage types, tropical types, sweet sorghums, and sorghum-sudangrass hybrids. Soils there contained 400 kg per hectare of nitrogen. The tropical sorghums and hybrids absorbed the most nitrogen from the soil, removing an average of 200 kg and yielding more than 20 metric tons of dry matter per hectare in one season.

"We hoped for more, but the first year's growing season proved to be short and cool," says Moore. "Under normal conditions, some

[10] The companion report *Saline Agriculture* has more information on sordan grass and salt-tolerant agriculture. For a list of BOSTID reports, see page 377.

NEW LIFE FOR SALTY SOIL

Over the last few decades, irrigation has saved the world's food supply from catastrophe. But irrigation has a fundamental flaw: in the drylands where it is most used, evaporation leaves the site with a surplus of soda and salt. In their worst forms such "sodic" soils become self-sealing: their internal structure collapses so that water just sits uselessly on the surface. Sorghum, it turns out, can help.

Sorghum roots ooze large amounts of sugars. Ordinarily, soil microbes gobble these up, but sodic soils tend to be anaerobic and lack the right organisms. Instead, chemical processes break down the sugars in a way that releases carbon dioxide. A weak natural acid carbon dioxide reacts with the soluble alkalis (sodium carbonate and sodium bicarbonate) to form acetic acid and a little formic acid. These stronger acids, in turn, react with the insoluble alkalis such as calcium carbonate. Sorghum's overall effect is therefore to reduce the alkalinity and convert minerals into more soluble forms. When those wash away, the soil's natural porosity is reopened.

This process occurs with amazing efficiency. Researchers at the U.S. Department of Agriculture have reclaimed marginal sodium-affected soils using sorghum (mainly the forage types called sordan and sudangrass) after just one season. In fields so toxic that crops would not grow, they get respectable stands of barley and alfalfa after just one season of sorghum. Beans, a highly salt-sensitive plant, can be grown after two or three seasons of sorghum. Within one season it not uncommon for the alkalinity to drop a full pH unit and the calcium solubility to increase tenfold. At first, however, the plants come up scraggly, stunted, and yellow. This has been traced to iron deficiency, to which sorghums are very sensitive. But when the "acidification mechanism" kicks in, the iron concentration in the plant shoots up, they turn green and grow rapidly.

The process is much more than a way to reclaim soils. The researchers are also getting some of the highest dry-matter production recorded in feed-sorghum, especially during the hottest of the summer months. Dry weight up to 67 tons per hectare.*

* Information in this section is from Charles W. Robbins, U.S. Department of Agriculture, 3793 North 3600 East, Kimberly, Idaho 83341, USA.

tropical sorghums absorb as much as 300 kg of nitrogen and yield 25 tons of dry matter per hectare."

Sorghum is so efficient a scavenger that nitrogen levels in the foliage can actually build up to levels harmful to livestock. To address this possibility of nitrate toxicity, the researchers rated their sorghums for nitrate content. Most were at or near toxic levels, but the ensiling process (a lactic-acid fermentation; see Appendix C) removes any threat to the animals.

With further refinement, this process could prove to be a method for continuously stripping nitrogen (and perhaps other pollutants, both useful and hazardous) out of the wastes from cities and industries. "Sorghum-sudangrass hybrids are very popular now in Nebraska and other Central Plains and Midwest states," says Pedersen. "They could be put immediately to work consuming organic wastes."

WIND EROSION

Researchers the world over are working hard to keep sorghum alive, but James D. Bilbro, Jr., is more interested in sorghum dead. He wants to foil the winter winds that pick up soil from Texas farmland and whirl it away across the American landscape. Dead sorghum, it seems, is an answer.

Bilbro, a U.S. Department of Agriculture agronomist in Big Spring, Texas, is exploring ways to protect farmland during a long, cold, blustery winter when the crops have been harvested and the land is bare. Today, farmers in his part of the country normally put in a special crop to cover the land and keep the soil pinned down. The plants survive under the snow, and to get the land back for planting the main crops again, the farmers must eventually kill them with herbicides.

Bilbro asks: Why spend money on herbicides and risk the environment when nature could do the work? In late summer or fall he plants warm-weather crops and finds that they serve very well. Although dead by December, they cover at least 60 percent of the ground, thereby eliminating wind erosion.

Of the 16 crops Bilbro has tested, forage sorghum is the most promising. He thinks that farmers will soon start using it to protect soil because it will save them money, help the environment, and (because the sorghum plants live such a short time before the frost arrives) leave more moisture behind for the subsequent crops.

The technique is being developed in the Texas High Plains, but it may prove useful wherever wind erosion is a problem in the cold-weather zones.

This may seem like a minor use for a major food crop, but the potential is actually vast. Wind damaged 1.74 million hectares of

cropland and rangeland in the 10-state Great Plains area during the last wind-erosion season (November 1991 to May 1992). And more than 6 million hectares were reported to be vulnerable to losing their topsoil to the wind. And that was just in the United States.[11]

Weed Control

In previous times, farmers used many plants in crop rotations to control weeds. With the advent of modern herbicides, this practice was dropped in favor of continuous cultivation of the most profitable cash crop. Science is now documenting what these farmers knew—and perhaps too often have forgotten. One example from the United States involves sorghum.

Despite the fact that U.S. farmers apply nearly 200 million kg of herbicides every year, they lose $10 billion worth of crops to weeds. But one Nebraska farmer, Gary Young, doesn't buy any herbicides and his 100 hectares of crops are doing just fine. About 10 years ago, Young noticed that his fields produced fewer than normal weeds the year after he grew sorghum. Since then he has relied on sorghum, not chemicals.

Now there is increasing proof that sorghum is a weed killer that works. Frank Einhellig, a biologist at the University of South Dakota, and James Rasmussen, an ecologist at Mount Marty College of Yankton, South Dakota, recently completed 3 years of field trials on Young's farm. On test plots covering 6 hectares, they had Young plant strips of sorghum, maize, and soybeans, and they measured the number of weeds that came up in the following year's crop. The strips that had been planted with sorghum produced only one-third as many weed seedlings at crop-planting time. Even in midsummer—without herbicides or cultivation—the total weed biomass was still 40 percent less than that on the plots that had been planted to maize and soybeans the previous year.

The surprise is that sorghum suppressed broad-leaved weeds without affecting grasses. It is a selective "herbicide" and thus has special importance for cereal farmers. (It is also well known that broad-leafed crops following sorghum are likely to give poor yields.)

The active ingredients are thought to be phenolic acids and cyanogenic glycosides given off by sorghum's roots. Phenolic acids affect plant-cell membranes and thus reduce a plant's ability to absorb water. They also disturb cell division and hormonal activity, and seem to inhibit seed germination as well as the seedling's early growth and

[11] For more information, contact James D. Bilbro, Jr., USDA-ARS Conservation and Production Systems Research Unit, P.O. Box 909. Big Spring, Texas 79721-090. USA.

SORGHUM SAVES THE SEASON

As this book shows, sorghum is a remarkable crop, but even we were surprised to learn of the following recent experience.

In the area around Lubbock, Texas, cotton has long been king. The rains there fall in the spring (as well as fall) and the cotton thrives in the hot, dry months that follow. But in the spring of 1992, the rains and record low temperatures came during the planting season. Throughout the region, more than 800,000 hectares were lost because of the unusual conditions. The cool and damp released the soil diseases and pests that had built up over the years and the cotton seedlings quickly succumbed.

The Federal government declared the crop a total loss and authorized disaster payments for the farmers. The farmers, however, faced an unexpected problem: their land was bare and could blow away in the summer winds or wash away in later rains. They needed a ground cover. In desperation they decided to sow nearly 600,000 hectares to sorghum.

Even in this seemingly simple task there was a difficulty. The cotton fields had been treated with a weed killer that is both persistent and designed to kill grasses. Sorghum obviously could not survive. Then someone suggested that an old-fashioned farm implement called a "lister-planter" might work. Fifty years before, farmers used these double-moldboard plows but had since given them up as too old fashioned and too energy consuming.

Now, however, in the 1992 emergency, the countryside was scoured for any of the old plows that were still lying about. Some were found quietly rusting away behind various barns.

Instead of planting sorghum seed in the normal way on the ridges left by the lister, the farmers planted it in the furrows. There, the roots had better access to the soil moisture, but more importantly the toxic topsoil had been scraped aside.

Nothing more was done. The sandy land had already been treated with nitrogen for the cotton crop and—although most observers believed that the rains had probably already leached the fertilizer below root depth—everyone hoped that the combination of furrow-planting and sorghum's deep roots would ensure at least a solid stand to cover the land. A few went beyond that and hoped for a modest harvest of sorghum grain.

The crop was harvested in the fall of 1992. Even with the late planting, minimum preparation, and no inputs, it was a record for that parched area. The figure—4,500 kg per hectare—actually matched the national average for sorghum. Elevators overflowed

Typical scene near Lubbock, Texas in 1992. Part of the unexpected near-record harvest. (A.B. Maunder)

with the unexpected bounty and grain had to be mounded in huge piles in the city streets. Some of the piles were half a kilometer long. Coming on top of their disaster payments, the farmers made more money than ever!

Is it any wonder, therefore, that the cotton farmers of Texas now look on sorghum with new respect? Years before they had used it as a rotation crop, and now they would like to use it that way again. Planting sorghum one year in four, they think, should break the buildup of cotton pests and diseases in the soil and help avoid future failures of the cotton crop. It might also improve soil tilth, decrease erosion, and diversify the local agriculture.

development. Cyanogenic glycosides are known to break down into secondary substances that include cyanide. "Cyanide," Einhellig notes, "is a pretty strong inhibitor of any growth system."

In his latest technique, Gary Young plants sorghum in the fall and allows it to freeze during the winter. The dead sorghum almost completely suppressed weeds, particularly broad-leaved weeds, throughout the year. Snap beans and other crops planted in the residue the following season required almost no weed control.

Now, many of Young's neighbors also plant sorghum and are finding reasonable weed control without herbicides.

In Africa, these effects may be especially important. Today, weeding is perhaps the greatest of all drudgeries in African farming. Most is done by hand—some of it on hands and knees. Returning to the old ways might just solve the problem.

With the new findings in mind, it is possible that the ongoing switch from sorghum to maize may be exacerbating Africa's weed problems. In the future, though, sorghum may become the maize farmer's best friend. Rotations of the two may benefit both.

Crop Support

West African farmers use sorghum for supporting yam plants. They employ a special kind that has stalks like ramrods. The yam plants are extremely heavy so the fact that sorghum can hold them up is graphic evidence of its strength.[12]

Actually, it is even more remarkable than it appears at first. The sorghums support the crushing weight of yams even 8 months after their grain has matured and they have died. Farmers bend the sorghum stalks over to create an intertwined "trellis" about 1.2 m high. The yams are grown on this woven wall of *dead* stalks from the previous season's sorghum crop.

Few plants could withstand such treatment. The tentlike canopy of clambering yam plants entraps heat and moisture and fosters molds, mildews, and rots of many kinds. These sorghums, therefore must be very fungus-resistant, even when dead.

Little attention has ever been given to yam-staking sorghums. Latin America's traditional use of maize plants to hold up climbing beans has been extolled, but Africa's even more remarkable counterpart is little known.

These strong-stalk sorghums might be excellent for use with many climbing annuals, including, for example:

- Macroptilium—an extremely promising tropical forage legume

[12] The yam vines can be 3 m tall and weigh perhaps 50 kg.

whose yields rise dramatically if it can be kept off the ground, where it becomes affected by mildew.

- Winged bean—a climbing bean that could become a major crop of the tropics if cheap ways to support it can be found.
- The viny types of lima beans, common beans, common peas, and runner beans that tend to be the highest yielding varieties but are seldom grown because of the expense of staking them or the lack of poles.
- Beans, squash, or other climbing plants traditionally grown on maize. Switching to sorghum might extend this useful practice to locations too dry for maize.

SORGHUM IN INDUSTRIAL PRODUCTS

Strictly speaking, this book is about plants that produce food, but we cannot resist rounding out the sorghum story with a glimpse at this plant's actual and potential utility as a source of everyday items for industry and for people in their homes.

Fiber Resources

In the rural regions of Africa and Asia, people have devised many uses for sorghum stems. These include:

- Roof thatching;
- Sleeping mats and baskets (made from the peeled stems); and
- Strings in traditional musical instruments (in Nigeria, for example, the peeled bark is used this way[13]).

In China, a particularly strong type has been developed for its pliable, dense stalks. Usually known as galiang sorghum, it is used for constructing fences, walls, and many household items, including grain bins bigger than the beds of pick-up trucks.

Brooms

Broomcorn belongs to this special galiang group of sorghums. It is a special sorghum that is grown not for food, forage, or fuel but for the bristles that rise from its flower head (inflorescence). These stiff, very strong, strawlike projections can be up to 60 cm long. For several centuries, people have used them to make brooms and brushes.

[13] Information from S. Agboire.

Broomcorn was apparently developed in the Mediterranean region during the Middle Ages. (The original sorghums are thought to have come from Africa or India.) It was growing in Italy before the year 1596, and soon thereafter it was being cultivated in Spain, France, Austria, and southern Germany.

Before this sorghum's arrival, Europe's houses, warehouses, front steps, streets, and other places that accumulate dust, dirt, leaves, and horse manure were swept with loose bundles of straw. These not only fell apart quickly, they lacked the strength and springiness to properly flick dust and dirt out of cracks and crevices. Broomcorn, therefore, may well have been one of the most beneficial advances in European public health.

In the United States broomcorn became, if anything, even more important than in Europe. Benjamin Franklin is credited with introducing this strange sorghum. He apparently brought the seed from England in 1725 (when he was only 19) and grew the first broomcorn in North America. It took hold, however. In 1781, Thomas Jefferson listed broomcorn among six important agricultural crops of Virginia. It has been the basis for billions of long-lasting brushes and brooms ever since.

In the competition with man-made fibers and the vacuum cleaner—both of which should in theory have swept it aside—broomcorn is holding its own in the United States. Today, products made of this sorghum are used in millions of American households, warehouses, stores, factories, steel mills, smelters, cotton mills, and barns. They range from whisk brooms to yard brooms for rough sweeping and special purposes.

Considerable development of broomcorn subsequently took place in the United States, but apparently few (if any) other countries have given the crop much attention. This is certainly surprising and should be investigated. Dozens of countries—from Rwanda to Russia—still sweep with bundles of straw. For them, too, this sorghum with the wiry flowers might be a boon.

The broomcorn plant is unlike other sorghums. The stem is dry and hard. The kernels are small and are often enclosed in long ellipsoid husklike coverings (glumes).

The plant has been typecast as a source of brooms and brushes, but it could very well have other equally important uses. For instance, broomcorn stalks are used for paper in France. Reportedly, excellent yields of fiber are obtained by planting the crop very densely. The pulp is used to manufacture kraft paper, newsprint, and fiberboard.

Danish scientists have also made a good paneling using the chips from internodes. Similar products are beginning to be explored in Zimbabwe as well. However, insufficient work has been done to really know the possibilities.

Chinese researchers are using tall sorghums for making plywood. The process apparently works well and gives a product stronger than wood.[14]

Dyes

Moroccan leather is said to get its color from red dye extracted from special sorghums. These red-seeded varieties were raised in sub-Saharan Africa and in the old days were sent across the Sahara to Fez or elsewhere by caravan. Natural dyes (especially red ones) are increasingly in demand these days, so perhaps these types could be commercially produced once more (see box, next page).

Resins

There is a black-grain sorghum from Africa called "shawya" that shows promise in producing industrial resins.[15]

ANIMAL FEED

The United States probably leads the world in developing sorghum as a feedstuff. The plant is now a vital animal feed throughout the nation's warmer regions (see page 160).

Although it has been in the United States since the earliest days (see page 186), grain sorghum first became a major American crop in the 1930s, when dwarf cultivars were bred. These lent themselves to large-scale operations and combine harvesting, and the acreage began increasing. The grains were used exclusively for feeding livestock and became so valuable for this purpose that by shortly after World War II, sorghum had become the most important cash crop in Texas and was a valuable resource in several other states as well.

Then in the late 1950s male sterility was discovered in sorghum (see page 163). This made hybrids possible. Sorghums that had originated in South Africa, Ethiopia, and the Sudan were bred together to create hybrids, and yields jumped as much as 40 percent. This led, in turn, to vastly more plantings and even more American animals were soon living off sorghum grain.[16]

Today, the country produces about 19 million tons of sorghum grain each year, and millions of American cattle, pigs, chickens, and turkeys

[14] Information from F.R. Miller.
[15] Information from L.W. Rooney.
[16] In 1957, about 15 percent of U.S. sorghum had been the hybrid form; within 2-3 years, the figure exceeded 90 percent.

RED SORGHUM RISING

In parts of West Africa people grow a form of sorghum that is inedible (and may even be poisonous). The plant provides a windbreak around huts and along the edges of fields, but more importantly it provides masses of leaf sheaths. These rusty-colored, parchment-like wrappings, which surround the leaf stems, provide pigments that are traditionally used to color leather goods. Millions of suitcases, shoes, hats, baskets, book covers, and other products get their brilliant red hues this way. The scarlet flame of the famous "Moroccan leather" and of the fez have their origins in this particular sorghum plant (race caudatum).

Traditionally, bundles of leaf sheaths were extracted in a difficult and laborious cottage-industry process. Now, however, this time-consuming and uncertain technique is being updated. In Burkina Faso, Mouhoussine Nacro, head of the Organic Chemistry Laboratory at Ouagadougou University, has been developing a new and more versatile version since 1989. Indeed, he is opening up the potential for producing sorghum dyes on a massive scale.

Nacro's dye-extraction process uses simple techniques but modern materials. Basically, he and his colleagues crush the sorghum sheaths, add a solvent, separate the liquid emulsion, and centrifuge the result. This produces the pure pigment as a burgundy-red powder that is ready for use and can be safely stored.

The pigment, Professor Nacro has discovered, is a mixture of anthocyanins. The main component, apigenin, is the same natural coloring used by food industries in many parts of the world. Moreover, it is increasingly sought these days because synthetic food dyes are suspected of causing harm.

Red-sorghum leaf sheaths contain over 20 percent of the apigenin and are said to be the only known source of such large concentrations. They contain more than four times the amount in the skin of the red grape, currently the most common source.

Burkina Faso's new process can easily be reproduced on an industrial scale, and commercial production of dyes could result in a new and valuable use for sorghum—one that has widespread application throughout the developing world, but especially in West Africa.

are fattened on it. Production is centered in the Great Plains, and extends over a vast area from the Gulf of Mexico to the Dakotas (see map, page 160).

But the crop is a more important feedstuff even than that. Only about two-thirds of America's sorghum plants are harvested for grains, and most of the rest also goes for animal feed. They, however, are turned into forage or silage or are left in the fields for grazing. This use of foliage rather than grain developed after sudangrass was introduced in about 1909. This grass sorghum has since been hybridized with grain sorghums to yield the "sorghum-sudan" hybrids. These crossbreeds are now widely used in the dry regions of the Plains states as well as in the Southeast, where other forages are sometimes hit hard by midsummer droughts and pests.

Although sorghum has advanced rapidly during the last 50 years, the fact that Americans developed it mainly as a livestock feed is in some ways unfortunate: the varieties typically had brown or red seed coats and are only peripherally relevant to food production. Moreover, in the public mind the crop became stigmatized as "animal food." Only now is there a nationwide glimmering of appreciation for sorghum as something people can eat. Today, American farmers are growing more and more of these food-grain sorghums, abandoning the brown and red types and switching to those with yellow or white seeds.[17]

Broom Corn

[17] Even people who work with the crop think the name "sorghum" has too many bad connotations in the American public's mind. Researcher Bruce Maunder has suggested the name "sungrain," on the basis that the white. cream, and yellow grains are "sunlike" and the grain is directly exposed to the sun's rays from pollination to harvest.

12

TEF

Tef *(Eragrostis tef)* is a significant crop in only one country in the world—Ethiopia. There, however, its production exceeds that of most other cereals. Each year, Ethiopian farmers plant almost 1.4 million hectares of tef,[1] and they produce 0.9 million tons of grain, or about a quarter of the country's total cereals.[2]

The grain is especially popular in the western provinces, where people prefer it to all other cereals and eat it once or twice (occasionally three times) every day. In that area, tef contributes about two-thirds of the protein to a typical diet.

Most tef is made into *injera,* a flat, spongy, and slightly sour bread that looks like a giant bubbly pancake the size of a serving tray. People tear off pieces and use them to scoop up spicy stews that constitute the main meals. For the middle and upper classes it is the preferred staple; for the poor it is a luxury they generally cannot afford.

Unlike many of the species in this book, tef is not in decline. Indeed, farmers have steadily increased their plantings in recent years. The area cultivated rose from less than 40 percent of Ethiopia's total cereal area in 1960 to more than 50 percent in 1980.

Tef is so overwhelmingly important in Ethiopia that its absence elsewhere is a mystery. The plant can certainly be grown in many countries. Some has long been produced for food in Yemen, Kenya (near Marsabit), Malawi, and India, for example. Also, the plant is widely grown as a forage for grazing animals in South Africa and Australia.

Now, however, the use of tef as a cereal for humans is transcending the boundaries of Ethiopia. Commercial production has begun in both the United States and South Africa, and international markets are opening up. This is because Ethiopian restaurants have recently

[1] The common name is often spelled "teff' or "t'ef' in English. We recommend "tef': it is simple, unconfusing, and perhaps a good marketing name that might help the crop's future expansion and acceptance worldwide.

[2] According to statistics of the mid-1980s, tef produced 23 percent of Ethiopia's cereal grain. The others were sorghum (26 percent), maize (21.7 percent), barley (17 percent), and wheat (12.4 percent).

Tef production in the Ethiopian Highlands. Tef is a reliable cereal for an unreliable climate. Its straw (left) is as important to the farmer as is its grain (pile at right). (International Livestock Centre for Africa)

become popular in both Europe and North America. Many cities (including Washington, New York, Chicago, San Francisco, London, Rome, and Frankfurt, not to mention Tel Aviv) now have restaurants that rely on *injera,* as well as the convivial communal dining it fosters. And only tef can make authentic *injera.*[3]

The new appreciation of tef is also extending into the research community. These days scientists in Ethiopia and a few other countries are beginning to seriously study the plant and its products.

This is all to the good. Tef has much more promise than has been previously thought. It provides a quality food. It grows well under difficult conditions, many of them poorly suited to other cereals. Even in its current state it gives fairly good yields—about the same as wheat under traditional farming in Ethiopia. And it usually produces grain in bad seasons as well as good—an invaluable attribute for poor farmers and of special benefit to locations beset by changeable conditions.

However, along with its advantages tef has serious drawbacks, mainly stemming from its tiny seeds, high demands for labor, lack of development, and difficult cultural practices. All in all, at this stage at least, it is neither easy to grow nor easy to handle.

PROSPECTS

To chart tefs future—both its course and final destination among world cereals—cannot now be done with confidence. This will become clearer as the current research efforts begin producing more results. Nonetheless, there are good reasons for optimism that tef's technical limitations can be overcome and that it can rise to be a specialty crop in a number of nations. It could happen quickly. Indeed, *injera* is such a fascinating food (half pancake, half pasta) that it has the potential to eventually become well-known worldwide.[4]

Africa

In Ethiopia, the plant's stable yield under varying conditions, as well as the grain's good storage properties, palatability, and premium prices, will likely make tef ever more attractive.[5] However, although

[3] *Injera* can be made from other grains, but when made from tef it keeps its soft and spongy texture for 3 days; when made from wheat, sorghum, or barley it hardens after only a day. Buckwheat is perhaps the closest substitute.

[4] Something similar is now happening with the tortilla, the round flat bread of Mexico and Central America, which is being sold in supermarkets throughout the United States and is also showing up ever more frequently in other parts of the world. On the open market in Ethiopia, its grain always commands a price substantially above that of other cereals.

[5] On the open market in Ethiopia, its grain always commands a price substantially above that of other cereals.

INJERA

Perhaps the most intriguing of all the world's staples, *injera* is a bread like no other. Moist, chewy, and almost elastic, it has a unique look and feel. A very correct British gentleman visiting Ethiopia in the mid-1800s tried to explain the experience of eating *injera:* "fancy yourself chewing a piece of sour sponge," he said, "and you will have a good idea of what is considered the best bread in Abyssinia." But these days people are not so closed-minded. Indeed, the search for new tastes and new culinary sensations is becoming a force that is opening up the food industries of affluent nations. *Injera* is now winning converts all over the world. It is served in fine restaurants in Europe, North America, and Israel and is receiving an enthusiastic welcome.

prospects for raising its production seem good, substantial increases will probably occur only after its labor requirements are reduced.

Tef may also come to benefit other African countries, notably some that today face food-production problems. The plant's resistance to diseases, pests, and heavy soils give it special appeal.

Several of tef's relatives are valued forages in the world's arid zones,[6] and tef itself might also have a future as a fodder. Indeed, in southern Africa it is already used extensively, having originally fed the horses and oxen of the Boer War almost a century ago. Tef hay is of such quality that South African farmers prefer it over all others for feeding, their dairy cattle, sheep, and horses (see page 230).

Moreover, this grass is exciting South Africans as a "quick fix" for holding down bare soil and thereby baffling erosion while more permanent ground covers establish themselves.

Humid Areas

Prospects probably low. For Africa's humid areas, tef's prospects are unknown because trials have not been conducted (or at least not reported). However, the crop comes from a relatively dry environment and probably has little or no potential in a hot and steamy one.[7]

Dry Areas

Good prospects. Tef is a reliable cereal for unreliable climates, especially those with dry seasons of unpredictable occurrence and length.

Upland Areas

Good prospects. Most of Ethiopia's tef is produced at moderate elevations, but it has long been common on the high plateau and is being slowly introduced to higher and higher locations. Its future contribution to the rural economy of these and other African highlands appears to be substantial.

Other Regions

Tef holds promise for many countries beyond Africa. Mexico, Bolivia, Peru, Ecuador, India, Pakistan, Nepal, and Australia might well adopt it. In addition, this plant's rapid maturity and inherent cold tolerance may open new areas of grain cultivation for high latitudes where growing seasons are short—Canada, Alaska, the Soviet Union,

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[6] These are usually called "love grasses" as reflected in the botanic name, which is derived from Eros (god of love) and grostis (grass). Weeping lovegrass *(Eragrostis curvula),* from southern Africa, is widely planted in the southwestern United States, for example.

[7] It is true that it is grown even in Ethiopia's Ilubabor province where the rainfall is very high, but mostly on steep slopes that quickly shed the runoff.

and northern China, for instance. It might also become important to Israel, which has a rising Ethiopian population.[8]

Some observers see tef as a promising new grain for the United States as well. They point out that it is nutritious enough to be a "health" food and tasty enough to be a gourmet food.[9] A company in Idaho already produces it on a commercial scale and supplies markets nationwide (see box). Tef is also being produced on farms in Oklahoma, where it is harvested by machine and sold under contracts from food companies eager to buy it.[10] These experiences, limited as they are, are probably laying the groundwork for a mass-produced specialty grain that will remain a part of the American food system.

USES

Tef grain comes in a range of colors from milky white to almost black, but its most popular colors are white, red, and brown. By and large, the darker the color, the richer the flavor. Although blander in taste, the white seeds command the highest prices. However, the red and brown seeds come from plants that are hardier, faster maturing, and easier to grow. In addition, tef aficionados prefer their more robust flavor.

Tef contains no gluten—at least none of the type found in wheat. For this reason, Americans with severe allergies to wheat gluten are among those buying tef these days. Despite the seeming lack of this "rising" protein, *injera* is a puffy product, somewhere between a flat bread and a raised one.

In Ethiopia, tef flour goes into more than just *injera.* Some is made into a gruel *(muk),* some is baked into cakes and a sweet dry unleavened bread *(kita),* and some is used to prepare homemade beverages. In the United States, it is recommended as a good thickener for soups, stews, and gravies, and, at least according to one promotional pamphlet, "its mild, slightly molasses-like sweetness makes tef easy to include in porridge, pancakes, muffins and biscuits, cookies, cakes, stir fry dishes, casseroles, soups, stews, and puddings."[11]

As fodder, the tef plant is cheap to raise and quick to produce. Its straw is soft and fast drying. It is both nutritious and extremely palatable to livestock. Its leaf:stem ratio (average 73:27) is high, its

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[8] Israel in recent years has been importing tef from the United States, South Africa, and Ethiopia.

[9] "I am using it constantly in my cooking—it makes most wonderful waffles and pancakes, for example," notes botanist Fred Meyer of Washington, D.C.

[10] Information from C.L. Evans.

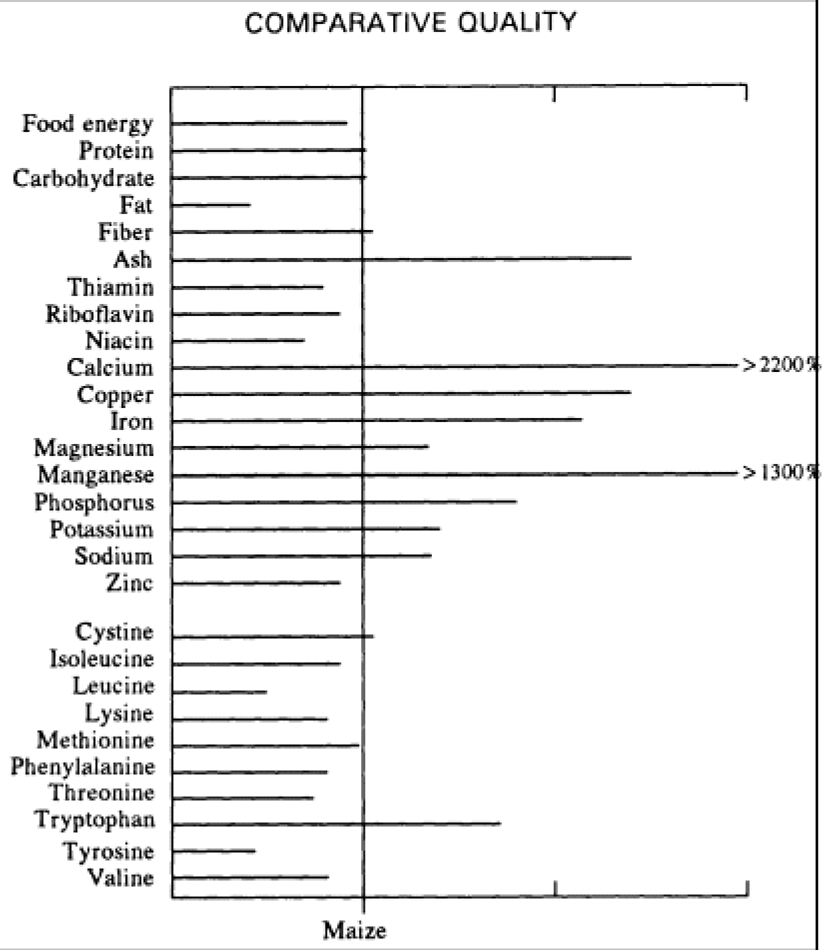
[11] A recent book, *Whole Grain Gourmet,* by R. Wood (William Morrow, 1991), includes many up-scale tef recipes.

NUTRITIONAL PROMISE

Main Components		**Essential Amino Acids**	
Moisture (g)	11	Cystine	1.9
Food energy (Kc)	336	Isoleucine	3.2
Protein (g)	9.6	Leucine	6.0
Carbohydrate (g)	73	Lysine	2.3
Fat (g)	2.0	Methionine	2.1
Fiber (g)	3.0	Phenylalanine	4.0
Ash (g)	2.9	Threonine	2.8
Vitamin A (RE)	8	Tryptophan	1.2
Thiamin (mg)	0.30	Tyrosine	1.7
Riboflavin (mg)	0.18	Valine	4.1
Niacin (mg)	2.5		
Vitamin C (mg)	88		
Calcium (mg)	159		
Chloride (mg)	13		
Chromium (µg)	250		
Copper (mg)	0.7		
Iron (mg)	5.8		
Magnesium (mg)	170		
Manganese (mg)	6.4		
Phosphorus (mg)	378		
Potassium (mg)	401		
Sodium (mg)	47		
Zinc (mg)	2		

Tef grains are reported to contain 9-11 percent protein, an amount slightly higher than in normal sorghum, maize, or oats. However, samples tested in the United States have consistently shown even higher protein levels: 14-15 percent.

The protein's digestibility is probably high because the main protein fractions—albumin, glutelin, and globulin—are the most digestible types. The albumin fraction is particularly rich in lysine. Judging by the response from Americans allergic to wheat, tef is essentially free of gluten, the protein that causes bread to rise. Nonetheless, tef used in *injera* does "rise" (see page 219).



The level of minerals is also good. The average ash content is 3 percent. Tef is reported rich in iron, calcium, potassium, and phosphorus. The iron and calcium contents (11-33 mg and 100-150 mg, respectively) are higher than those of wheat, barley, or sorghum. In Ethiopia, an absence of anemia seems to correlate with the levels of tef consumption and is presumed to be due to the grain's high content of iron.

However, some samples of tef have failed to show the extraordinary levels of iron. Part of the iron may well come from dust and dirt that clings almost uncannily to these tiny grains. Washed seeds have shown a level of iron of about 6 mg, much less than the reported figures but still a remarkable amount.

digestibility (65 percent) relatively high, and its protein content (1.95.2 percent) low but nonetheless valuable. Ethiopian farmers rely on it to strengthen their oxen at the end of winter, a time when fresh grass is unavailable but the plowing season is coming on.[12]

Tef has as much, or even more, food value than the major grains: wheat, barley, and maize, for instance. However, this is probably because it is always eaten in the whole-grain form: the germ and bran are consumed along with the endosperm.

In Ethiopia, tef straw is the preferred binding material for walls, bricks, and household containers made of clay.

NUTRITION

Tef seeds appear similar to wheat in food value; however, they are actually more nutritious. There are two reasons for this: (1) the seeds are so tiny that they have a greater proportion of bran and germ (the outer portions where nutrients are concentrated); and (2) because the seeds are so small, tef is almost always produced as a whole-grain flour.[13]

For a grain, tef is rich in energy (353-367 kcal per 100 g). Its fat content averages about 2.6 percent.

In most samples, the protein content is as good as, or better than, that of other cereals. It ranges from 8 to 15 percent, averaging 11 percent. The protein, as in most cereals, is limited by its lysine level. Otherwise, however, it has an excellent balance of essential amino acids.[14] Indeed, two nutritionists, having surveyed all the common foods of Ethiopia, commented: "[W]e want to draw attention to the high values for methionine and cystine found in tef. . . . The protein from a mixture of tef and a pulse will give a near optimal amino acid mixture with regard to both lysine and to the sulfur-containing amino acids."[15]

The vitamin content seems to be about average for a cereal, but making *injera* involves a short fermentation process, and the yeasts generate additional vitamins. The value of the grain is thus enhanced.

The mineral content is also good (average ash content 3 percent). The iron and calcium contents (0.011-0.033 percent and 0.1-0.15 percent) are especially notable. In Ethiopia, an absence of anemia seems to correlate with the areas of tef consumption, presumably due to the grain's good iron content.

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[12] Tef fodder is therefore a vital component of Ethiopia's whole farming system, a point often overlooked by those who consider only the grain. Information from G. Jones.

[13] Refined flour can be made, however. With appropriate screening it can be sifted away from the bran and the germ. Information from W. Carlson.

[14] In Ethiopia, it is said that a daily intake of one *injera* pancake supplies enough of these amino acids to sustain life without another protein source; two are sufficient to ensure good health.

[15] It is notable that Ethiopians commonly mix fenugreek *(abish),* lentils, peas *(ater).* or faba bean *(bakela)* with *injera* batter, a practice that satisfies this nutritional criterion.

AGRONOMY

Ethiopian farmers grow tef either as a staple or as a standby. As a staple, they plant it like other cereals, but they normally sow it late and harvest it well into the dry season. As a standby, they wait until their main crop—maize, sorghum, or maybe wheat—shows signs of failing. Then they sow a fast-maturing tef as a backup source of sustenance in case of disaster.

Even where other cereals offer reasonable reliability and substantially higher yields, Ethiopian farmers still include a field or two of tef. Not only does it bring them high prices, its late sowing date allows them to grow and harvest both crops.[16]

In Yemen, tef is known as a lazy man's crop: the farmers merely toss seed onto moist soil following flash floods and then return after about 45 days to collect the grain.[17]

No matter how it is grown, tef requires little care once it is established. Its rapid growth stifles most weeds; few diseases and pests attack it; and it is said to produce well without added nutrients. However, in most places tef will respond to fertilizers.[18]

HARVESTING AND HANDLING

Tef threshes well with standard methods and equipment. Very early-maturing types are ready to harvest in 45-60 days; early types in 60120 days; and late types in 120-160 days.

Yields range from 300 to 3,000 kg per hectare, or even more. Although the national average in Ethiopia is 910 kg per hectare, yields of 2,000-2,200 kg per hectare are considered routinely attainable if good agronomic practices are carefully followed. Yields of 2,000 kg per hectare have been achieved on South African farms also, although storms have sometimes leveled the fields, resulting in large losses.[19]

The grain is easy to store and will survive for many years in traditional storehouses without damage by insects. This makes it a valuable safeguard against famine.

[16] Information from Sue Edwards.

[17] Information from H. Moss.

[18] In South Africa it has been found that forage (and no doubt seed) yields improve dramatically when up to 80 kg of nitrogen are added per hectare. However, the current varieties put more growth into straw than seed, a feature not necessarily disliked by farmers. Information from N.F.G. Rethman.

[19] Information from N.F.G. Rethman.

Injera, the most important bread in Ethiopian cooking, is normally made from tef. It is a thick spongy pancake in which other food can be sandwiched or rolled. The pancakes are only a few mm thick but can be up to half a meter across. (Panos picture)

LIMITATIONS

The seeds are so small that this alone makes the crop hard to deal with. The fields are tedious to prepare, and it is difficult to get an even stand. Also, wind or rain can bury the minute seedling before it can establish itself. Threshing, winnowing, and grinding such tiny seeds by hand is very laborious. Handling and transporting them is also a problem because they tend to fall through any crack.

NEXT STEPS

Tef seems poised on the brink of becoming a resource for everyday foods, gluten-free specialty items, animal feeds, and erosion control. Ethiopian farmers, therefore, have much to teach nations the world over. The problem is that at this point few people have recognized tef's qualities. Activities are needed to spark interest and raise overall awareness of tefs status, potential, problems, and requirements. These could begin, for example, with conferences, monographs, newsletters, and publicity materials.

Although people in tef's homeland know more about the crop than anyone else, it is unrealistic to expect that Ethiopia can spearhead such activities, at least at present. An international global effort is called for. Luckily, tef is not a weed. Trials can be conducted in different parts of the world with little hazard. Although many countries could participate, the United States, South Africa, and Australia especially could help pioneer the selection of types for trials and eventual use worldwide.

Tef is also a challenge to the world's cereal scientists, agronomists, and food chemists. It is an interesting new cereal that few people know of at present. It seems to offer many possible benefits, but what its limits and potentials are in practice is still very uncertain.

Germplasm Collection and Evaluation

The germplasm in Ethiopia is potentially of worldwide importance. Since Ethiopia is the center of origin and the center of diversity for this crop, preserving its diversity is a prerequisite for all tef improvement. Actually, several thousand samples have already been collected. Although more undoubtedly remain, perhaps the most urgent task is to characterize the tef lines already available.

Plant Breeding

Until very recently, crossing tef was tedious. It was constrained to a few minutes at about dawn, and required supremely skillful personnel. Now, however, techniques have been developed that make the process quite straightforward and routine.

TEF PIONEERS

Until recently, Ethiopia's official commitment to tef research has been small compared with its investment in wheat, maize, and sorghum. However, several organizations have devoted their own efforts to boost the crop.

Both the Debre Zeit Agricultural Research Centre of Alemaya University of Agriculture and the Institute of Agricultural Research at Holleta Research Station near Addis Ababa have produced high-yield strains. Some of these get so heavy with grain that the stalk collapses.* Research is now under way to develop varieties with short, stiff straw to create high-yielding tefs that can benefit from heavy fertilizer use and irrigation without collapsing.

The Institute for Agricultural Research has also done research on tef with encouraging results at Debre Zeit. It has developed a variety, DZ 01-946, which has given yields of 1.78 tons per hectare.

There has also been increasing international interest. In England, London University's Wye College is doing systematic breeding. In Israel, the Volcani Centre is carrying out tef research trials. And in the United States, Wayne and Elizabeth Carlson of Caldwell, Idaho, have been developing cultivars and processing techniques for farmers both domestic and foreign (see box, opposite).

* This was a problem with early high-yielding wheats until short-stemmed varieties were bred in Mexico—a combination that led to the Green Revolution varieties that for 20 years have fed the added millions in Asia who would otherwise have starved.

A program of tef improvement by plant breeding—combining the desirable qualities of several parents in a planned way—might well bring big advances. Objectives include early maturity, short and stiff straw, disease resistance, and higher harvest index.[20] One variety created in Ethiopia has yielded 3,560 kg per hectare.

Other targets for improving the crop, especially for large-scale commercial production, include larger grain size, less shattering of seeds, and quicker drying seeds.[21]

Agronomy

In Ethiopia, large yield improvements can be achieved by applying techniques that are already known: careful land prepara

[20] A variety called "munité" seems especially valuable in this regard because it is very short (40 cm), early maturing, and has a high harvest index.

[21] The ability to harvest drier seeds (than possible at present) would likely reduce harvest losses and increase tefs acceptance by farmers worldwide.

TEF IN THE UNITED STATES

Wayne and Elizabeth Carlson are among the handful of non-Ethiopians who have begun growing tef for food. The crop is thriving on their farm near Caldwell, Idaho. In the harsh, dry valley on the Idaho-Oregon border, their fields are now producing Ethiopia's favorite food grain.

Wayne became aware of tef while working as a biologist in Ethiopia. On returning to the United States, he planted some. Within 5 years the Carlsons had progressed from growing a few varieties in their backyard to harvesting 200 acres of four selected strains, as well as threshing, milling, and packaging thousands of kilos of tef seed each year.

The Carlsons' tef flour now goes to natural-food markets nationwide as well as to the numerous Ethiopian restaurants that have been springing up in major cities to serve Americans as well as an estimated 50,000 Ethiopian immigrants and students. Their long-range goal is to make tef a new option among America's cereal crops.

Tef's homeland has not been overlooked. Each year the Carlsons return a portion of the grains they have bred to Ethiopia for trials and for farmers. Last year, they donated 16,000 kg of seed to a relief agency for planting in Ethiopia.

Wayne Carlson says that the Western world should pay more attention to tef. For centuries the plant's adaptability and nutritional value have helped Ethiopian highlanders maintain their independence in the harsh surroundings in which they live, he notes.

tion, use of selected seeds, fertilization, sowing and weeding at the optimum time, and disease and pest control, for example. Yields can also be increased by mechanization. Sowing methods require special attention.

TEF IN TRANSVAAL

In 1886, the Royal Botanic Gardens at Kew, England, obtained tef seed from Abyssinia and distributed it to various botanic gardens and other institutions in India and the colonies. In its first issue (1887), Kew's *Bulletin of Miscellaneous Information* advocated introducing the crop "to certain hill stations in India, to elevated portions of our colonial empire, and indeed to all places where maize and wheat cannot be successfully cultivated."

These efforts stimulated tef trials in various parts of Africa, Asia, and Australia. As a result, many reports on the plant's performance were received.

Perhaps the most effective introduction was to the Transvaal (which was not then under direct British control). Growers there found that "it makes very rapid growth, maturing in seven or eight weeks from the time of sowing, and if cut before the seed develops, a second crop can be obtained from the same stand; it makes an excellent catch-crop for hay, two successive cuttings being obtainable during the summer on unirrigated land. The plants seed heavily, our yield of seed from a small plot has been at the rate of about three-fourths ton per acre [1.875 tons per hectare]; the seedlings are not readily scorched by the intense heat of summer. On account of the soft, thin straw, it dries and cures very quickly."

But despite the good results, tef took off only by a fluke. As is usually the case with new farm crops, it did not sell well when first offered. The story goes that a farmer, having more tef hay than he required, sent the surplus to the Johannesburg market. It sold poorly—none of the buyers knowing the stuff—and it finally went for animal bedding. It is softer than the ordinary bedding (normally cut from sedges and *Arundinella eckloni*), and a buyer

Ornamentals

There is now an explosion of interest in ornamental grasses in Europe, the United States, and Japan. With its upright, compact habit, its often brilliantly colored leaves (many color combinations are possible), and open feathery panicles, tef is exceptionally

attractive. The development of selected strains might create a small but profitable market niche as an ornamental.[22]

selected one lot for a racing stable. Rumor has it that the stable owner found his racers eating their bedding in preference to their feed! To his surprise they also began to put on condition. Then he bought up all the tef on the market and called for more. Others soon got wind of this and the price rose. Tef was accepted and became a fodder of notable importance to the Transvaal in the early twentieth century. (For instance, during the Boer War it probably fed the horses on both sides.)

"Tef has raised scores of small Transvaal farmers from poverty to comparative comfort, and has been largely instrumental in putting the dairy industry of the Witwatersrand on its feet," wrote Joseph Burtt Davy in the *Kew Bulletin* of 1913. "The opinion has been expressed by our farmers that 'if the Division of Botany of the Department of Agriculture had done nothing else, the introduction and establishment of tef as a farm-crop would have more than paid South Africa the whole cost of the Division for the ten years of its existence.' "

In the Transvaal, as well as in other parts of South Africa, tef is often sown with its relative, weeping lovegrass *(Eragrostis curvula).* This perennial has been developed in South Africa into an almost incredible array of types for land protection and reclamation purposes. It is providing outstanding erosion control on toxic, dry, degraded, and infertile slag heaps and other problem sites where nothing previously would grow. As an erosion-fighting plant, weeping lovegrass is better than tef because it is a perennial whose natural staying power keeps the land covered as the seasons go by. But while tef may not be good at such a "long-distance event," it is very good as a "sprinter." Thus tef is used to produce a fast cover that protects the site while its slower cousin is finding its legs.

Forages

In South Africa various productive races have been selected for hay production. These deserve to be exploited elsewhere. Also, it seems likely that a wealth of new types, adapted to many

[22] This possibility is already being explored in the United States. Information from W. Carlson.

different conditions, can be created from Ethiopia's broad germplasm base.

Erosion Control

It seems likely that demand will increase worldwide for nonweedy annual grasses that can serve as temporary ground covers. South Africans are now using tef as a "nurse crop" that quickly covers the ground and fosters the establishment of perennial grasses sown along with it. This should be tested elsewhere, too. In South Africa it is already used in mixtures to protect road cuts, open-cast mine workings, stream banks, and other erodible sites.[23]

Black Cotton Soils

Tef has evolved on the Ethiopian highlands on vertisol (black cotton) soils that frequently get waterlogged. Few other cereals can be grown there. In fact, tef is able to withstand wet conditions perhaps better than any cereal other than rice. It even grows in partly waterlogged plots, as well as on acidic soils.[24]

Vertisols are a problem in many parts of the tropics. They are cracking clays that regularly heave and sag and split.[25] Few crop plants can withstand such soil abuse. Tef might be a savior for such sites. India, in particular, has vast areas of these "impossible" soils.

SPECIES INFORMATION

Botanical Name

Eragrostis tef (Zucc.) Trotter

Synonyms

Poa abyssinica Jacq.; *Eragrostis abyssinica* (Jacq.) Link

Common Names

Afrikaans: tef, gewone bruin tef (ou bruin)
Arabic: tahf
English: tef, teff, Williams lovegrass
Ethiopia: tafi (Oromo/Afar/Sodo), tafe-e (Had); t'ef, teff, taf(Amarinya, Tigrinya languages)
French: mil éthiopien
Malawi: chimanganga, ndzungula (Ch), chidzanjala (Lo)

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[23] It is often sown with its relative *Eragrostis curvula.* This perennial has been developed in South Africa into an almost incredible array of types for land protection and reclamation purposes. They are providing outstanding erosion control on toxic, dry, degraded, and infertile slag heaps and other problem sites where nothing previously would grow. (Information from J.J.P. van Wyk, see research contacts.)

[24] Information from H. Kreiensiek.

[25] Early in the growing season, these soils become waterlogged and go anaerobic; later they crack and dry out, breaking off the roots of plants that have survived the trauma. They also get so gooey during the rains that machinery and people cannot move across them.

Description

Tef is an annual tufted grass, 30-120 cm high, with slender culms and long, narrow, smooth leaves. It is shallow-rooted. Its inflorescence is a loose or compact panicle. The extremely small grains are 1-1.5 mm long, and there are 2,500-3,000 seeds to the gram.

The plant employs the C4 photosynthetic pathway, using light efficiently while having low moisture demands. It is a tetraploid with a chromosome number of 2n = 40.

Distribution

Tef was grown in Ethiopia before recorded history and its domestication and early use is lost in antiquity. Its most likely ancestor is *Eragrostis pilosa,* a wild species that looks very similar and has the same chromosome number. Samples claimed to be tef have been found in the tombs of the Egyptian pharaohs. The plant is still harvested in the wild—and wild tef is eaten, sometimes on a considerable scale, in mixtures with other wild grains (see wild grains chapter, page 251).

Cultivated Varieties

There are many different types of tef. The narrow panicled "muri" (rat-tailed) types and the dwarf, semi-prostrate and short-lived "dabi" types, for example. Both of these differ strikingly from the tall, loose-panicled varieties that are most commonly grown.

As noted, three main color types are recognized in Ethiopia:

- White tef *(thaf hagaiz).* This slow-maturing form is grown in the cool season. It is superior for grain. However, it makes higher demands on the soil and can be grown only below 2,500 m altitude. In South Africa this type is being developed as an export grain.
- Red and brown tefs. These are quick maturing and superior for fodder. In Ethiopia they are usually grown above 2,500 m. Elevation seems irrelevant, however, because this is the type being used in South Africa as a fodder crop.

Environmental Requirements

Daylength

The exact requirements are unknown. In South Africa the plant seeds freely between 22 and 35°S latitude (average daylength, 12 hours). In Ethiopia, the latitude is between 5°N and 10°N (daylength, 11-13 hours).

BRINGING THE DEAD TO LIFE . . . . . . JUST ADD WATER

Although the seeds of many flowering plants can survive complete dehydration, all other plant parts die when they dry. Certain plants, however, have the seemingly miraculous ability to recover from desiccation. Within hours of being watered, their leaves, stems, and sometimes even flowers spring back to life. Tissues that were brown and seemingly irreparably damaged take up a healthy green color and resume active growth once again.

No one knows how many species can defy drought in this way, but it is a small number, and at least four of them are African grasses related to tef. This suggests that crossbreeding them with tef might yield hybrids combining the qualities of a good cereal with the ability to withstand the ultimate drought.

This fascinating possibility of a fail-safe crop that can bounce back from complete desiccation is being studied by Australian plant physiologist Don Gaff.* So far, his biggest problem (other than getting funds for such far-out research) has been to get tef to breed with its "resurrection relatives." Fertility barriers between the species are too high for natural pollination, so Gaff has adopted a process known as "somatic hybridization." Using electrical pulses, he induces cells from the leaves to fuse as if they were normal pollen and egg cells. To accomplish this, he must first strip the cells of their cellulose walls. The fused cells resulting from this forced marriage can be regenerated into whole plants using the techniques of tissue culture.

Although only at the beginning of this challenging work, Gaff has already found four eligible partners for tef. These are:

- *Eragrostis paradoxa.* A rare species collected in Zimbabwe, this relatively low-growing grass with very fine leaves has remarkable resilience and has survived growing on soils only 1 cm deep.
- *Eragrostis hispida.* This species, too, was from Zimbabwe and is taller and has broad, hair-covered leaves.
- *Eragrostis nindensis.* A vigorous grower, widely distributed in Namibia and other arid areas of southern Africa, this wild tef is locally valued as sheep fodder.
- *Eragrostis invalida.* Gaff's sample of this perennial was collected in the Tingi Mountains near the Niger River's source in Sierra Leone. Tallest of the four, it is still only 60 cm high; short rhizomes assist its clumps to spread.

* Don F. Gaff, Department of Ecology and Environmental Biology, Monash University, Wellington Road, Clayton, Victoria 3168, Australia.

Rainfall

The average annual rainfall in tef-growing areas is 1,000 mm, but the range is from 300 to 2,500 mm. Tef resists moderate drought, but most cultivars require at least three good rains during their early growth and a total of 200 to 300 mm of water. Some rapid-maturing cultivars can obtain the 150 mm they need from water retained in soils at the end of the normal growing season. Most tef in South Africa is planted in the 500-800 mm summer rainfall zone.

Altitude

Tef can be grown from near sea level to altitudes over 3,000 m. It is particularly valued for areas too cold for sorghum or maize.[26] It has a wider altitudinal range than any other cereal in Ethiopia. Most is cultivated between 1,100 and 2,950 m.

Low Temperature

While tef has some frost tolerance, it will not survive a prolonged freeze.

High Temperature

Tef tolerates temperatures (at its lower altitudinal range) well above 35°C.[27]

Soil Type

Tefs tolerance of soil types seems to be very wide. As noted, it performs well even on the black cotton soils that are notoriously hostile to crops and farmers. In fact in South Africa it is already very popular on such soils.[28] Soil acidities below pH *5* are apparently no problem for tef.[29]

[26] In Lesotho, for instance, it occurs at altitudes up to 2,000 m, where temperatures drop to -15°C. Information from H. Kreiensiek.

[27] It is, for example, grown with irrigation at Gode on the Wadi Shebele River in the Ogaden where the temperature reaches 50°C.

[28] The farmers, however, use twice the normal seeding rate. Information from N.F.G. Rethman.

[29] Information from H. Kreiensiek.


SJH

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Other Cultivated Grains

Some of the neglected cereals described previously—sorghum, finger millet, and pearl millet, for example—are not, strictly speaking, "lost." But there are a number of African food grains that are indeed truly overlooked by all of modern science. Most of these come from wild grasses (see next chapter), but some are from plants cultivated by farmers on at least a small scale. These last, Africa's least known grain crops, are discussed here.

GUINEA MILLET

Guinea millet *(Brachiaria deflexa)* is perhaps the world's most obscure cereal crop. It is cultivated by farmers only in the Fouta Djallon plateau, a rather remote region of northwestern Guinea. Little, if anything, has been done to improve this crop, yet where it is grown the people value it highly. They grind its soft seeds into a flour, which is used for cakes and fritters.

Although this domesticated plant is grown only in this one area of the Guinea highlands, the wild form is spread throughout the Sahelian zone from Senegal to the Horn of Africa as well as in coastal savannas from Ivory Coast to Cameroon. This wild form is also harvested for food.[1] The main difference between the two is that the cultivated type has much larger grains and is nonshattering (holds its seeds).

This plant grows to about I m tall, and looks so much like fonio (see Chapter 3) that for decades it was classified as just a special fonio variety.[2] However, it has botanical differences and bears larger grains.

Although unstudied by agronomists, guinea millet appears to have useful characteristics. For instance, some types mature so quickly

[1] Another wild relative (*Brachiaria stigmatisata*), found from the Gambia to the Sudan, is widely gathered as a cereal as well.

[2] This was previously considered a cultivar of fonio (*Digitaria exilis,* see fonio chapter, page 59). Locally, it is often called "fonio with thick seeds."

Brachiaria species, thought to be guinea millet, growing in Fouta Djallon region of Guinea. (B. Simpson)

they take only 70-75 days from planting to harvest (most, however, require 90-130 days). Commonly, farmers use these fast-maturing guinea millets to fill in any gaps in their fields of sorghum, maize, or other grains. This allows them to get a full harvest from those fields.[3] To achieve truly quick growth, however, a rich and well-drained soil is required.

Guinea millet deserves recognition and attention from scientists and others interested in helping food production and agriculture across West Africa. Despite its current obscurity, it just might have a big future both there and in other regions.

EMMER

Emmer (*Triticum dicoccum*) is not strictly African; it is a wheat that originated in the Near East. Indeed, it was one of the first cereals ever domesticated[4] and was part of the early agriculture of the Fertile Crescent. Farmers had it in fields perhaps as far back as 10,000 years ago. For several thousand years it remained a major cereal throughout the Middle East and North Africa. Then people switched to durum wheat—the type now used worldwide to make spaghetti, macaroni, and other pastas. In fact, durum wheat (*Triticum turgidum* var. *durum*) probably originated from emmer by mutation. Farmers preferred it because its grain was free-threshing (the seed fell out of its husk quite easily), and during the past 2,000 years or so the older form, emmer, became an abandoned waif.

Despite its Middle Eastern origin, emmer nonetheless has an ancient African heritage. It reached Ethiopia probably 5,000 years ago, perhaps more, and it survives there to this day.[5] Whereas it virtually disappeared elsewhere, emmer comprises almost 7 percent of Ethiopia's entire wheat production. Even in what is a major, modern, wheat-growing region, it remains important. Indeed, far from abandoning it, farmers in Ethiopia's highlands have over the last 40 years increased the percentage of emmer that they grow.[6]

Emmer, locally known as *aja,* is used in various ways. Some is ground into a flour and baked into a special bread (*kita*). Some is crushed and cooked with milk or water to make a porridge (*genfo*). And some is mixed with boiling water and butter to produce a gruel. With emmer's high protein content and smooth, easily digested starch, the gruel is especially favored by invalids and nursing mothers.

[3] Portères, 1976.
[4] Together with two-rowed barley (see page 245) and einkorn *(Triticum monococcum).* which, like emmer, is a predecessor of modern wheat.
[5] It also survives as a crop in a small way in Yugoslavia, India, Turkey, Germany (Bavaria), France, and other countries. Information from J. Harlan.
[6] Tesemma, 1986.

RESURRECTING BIBLICAL WHEATS

Emmer (see previous page) is just one of several ancient wheats that could help the modern world. Two others are being rescued in Europe. The efforts summarized below could be the spur for similar endeavors to bring emmer back as a major crop as well.

Einkorn

Until recently everyone thought that einkorn, perhaps the earliest of all cultivated wheats, was essentially extinct. But in 1989, botanist Jacques Barrau reported the following experience in the south of France.

"In 1971, I decided to look at all the food plants in the mountains of Vaucluse, where my father's family had its origin. From childhood memories, I knew that a kind of porridge was a popular peasant dish there in winter. I started looking for the cereal used for that purpose and found to my surprise that it was the neolithic [Stone Age] einkorn, *Triticum monococcum.* The crop was still being grown there, as well as in some localities in the Southern Alps, as a subsistence cereal of which the unground grain was used to prepare this special porridge. This was unknown to my learned friends in French agricultural research.

"Today, this relict prehistoric wheat is beginning to find markets as a 'natural health-food,' and it sells at a price rather satisfying for the stubborn traditional growers who, through generations, had kept it in cultivation, just to satisfy their lasting taste for this porridge."

Spelt

For the Stone Age inhabitants of what is now south Germany, spelt (*Triticum spelta*) was the main food source. Later, however, this primitive winter cereal was abandoned—not because of inferiority but because farmers found other wheats easier to grow. For one thing, spelt's grain had a close-fitting husk that made it harder to thresh, and its very long straw meant that summer winds could blow the plants down.

Now, spelt (or dinkel as it is usually called in Germany) is coming back as a crop. In this case, the driving forces behind its return are modern consumer preferences—notably the rising appreciation for good nutrition and for protecting the environment. Nutritionally speaking, spelt is very exciting. Breadmaking wheats in northern Europe generally contain around 11 percent

protein. Spelt averages between 14 and 15 percent; some types have even exceeded 17 percent. The grain also has greater concentrations of minerals and vitamins. Even with its lower yield, spelt can produce more protein per hectare than modern breadwheat. And a growing number of consumers are acclaiming the "nutty" taste of products baked from spelt flour.

Spelt's environmental advantages are proving even more important. "The kernel is protected against fungi or insects by the close-fitting husk," explains Christof Kling, head of wheat breeding at Hohenheim University in Stuttgart. "This means the crop is very appropriate for use in environmentally sensitive areas or where farmers want to use less pesticide, or even none at all."

In the old days, when people had to thresh grain by hand, the very attribute that helps to protect the grain against pests and diseases—the close-fitting husk—was an overwhelming disadvantage. But in our mechanized era it is inconsequential.

Like einkorn and emmer, spelt never disappeared entirely, but until recently it was grown in only a few isolated pockets in Germany, Belgium, Switzerland, and Austria. Now all that has changed. In fact, enthusiasm for this long-lost grain is so high that spelt in the early 1990s is being cultivated on over 6,000 hectares in Germany alone. Indeed, a special organization (the Dinkelacker Foundation) has been established to help foster this prodigal son's return from the Stone Age.

Emmer

Recently, researchers in Syria have become excited over emmer. Samples gathered from different parts of the country grew surprisingly well when planted at two ecologically different locations (Tel Hadya and Breda). A wealth of qualities soon became apparent. The researchers concluded that their samples were: "an important genetic reservoir of variability for useful characters such as earliness, short stem, high number of fertile tillers [see picture overpage], long spikes, dense spikes, high number of seeds per spike, weight of kernels per spike, and protein content."

They also noted that most of the emmers exhibited traits suitable for cultivation in the arid areas. "Tolerance to drought is also one of [the] traits, which could be used in breeding wheat for the dry areas," they said.

* This work was conducted by S. Hakim and M. Y. Moualla at Tishreen University, Lattakia, and by A. B. Damania at the International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo.

Emmer. This sample, with its remarkable number of separate seedheads (tillers), was discovered by researchers in Syria when a small collection of emmer seeds was planted at two ecologically different locations (see previous page). In addition to having more than 20 seedheads, this plant tolerates drought and its grain has a protein content of 18-21 percent. (A.B. Damania)

This "cereal that refuses to die" deserves better treatment from science and commerce. Its economic importance in Ethiopia alone makes it worthy of research attention. However, there might also be worldwide interest. Already, small projects to restore it to widespread modern use are under way in the United States and France (see box). The plant grows in a wide range of environments and can be produced in many parts of the world. The fact that it is the wheat family's "living fossil," little changed from wheat eaten in the times of the Bible and the Koran could give it special consumer appeal. But it can also stand on its own culinary merits. Pliny the Elder (AD 23-79) wrote that emmer wheat makes the "sweetest bread," and even today its virtues are hailed with similar plaudits.

On the face of it, emmer might also benefit the world's wheat-breeding programs. Already, its genes have conferred on the American wheat crop resistance to rust, a virulent fungal disease that in earlier times periodically devastated the nation's food supply.[7] Its other desirable characteristics include early maturity, drought resistance, and a high protein content.

BARLEY

Although barley (*Hordeum vulgare*) is probably not a native of Africa either, it also has been used in Ethiopia for at least 5,000 years. Indeed, Ethiopian barleys have been isolated so long that two of them, irregular barley and deficient barley, were for a time considered distinct species.

Among these two genotypes, as well as among the rest of the diversity of barley forms, can be found a wealth of promising types in addition to genes for use in the world's barley crop. In fact, Ethiopia's assorted barleys are said to be a vital part of its cultural heritage. Under normal circumstances each family sticks tenaciously to its own seed stock. Thus, over thousands of years, each family's stocks have evolved along separate and divergent lines and a vast diversity has resulted. Today, the fields are amazingly rich in different types. In fact, each farmer usually cultivates complex mixtures or even separate plots of quite distinct barleys.

Barley ranks third in terms of area (after tef and sorghum) in Ethiopia. However, its value goes far beyond just economics and nutrition. It is, in fact, deeply rooted in the cultural life. The Oromo people, for instance, consider it the holiest of crops. Their songs and

[7] For example, severe rust epidemics wiped out vast acreages of wheat in 1904, 1918, 1935, and 1953, each time sowing fear and high prices. In 1918, the harvest was so bad that the U.S. government had to declare "wheatless days," on which no wheat products could be sold.

ETHIOPIAN BARLEY IN NEW MEXICO

Although Ethiopia's barley is all but unknown elsewhere, at least one overseas group has attempted to grow it, and with considerable success. In the dry southwestern quarter of the United States, the Ghost Ranch, a facility sponsored by the Presbyterian church, has been growing it as one of its main cereal crops since 1983. Following are comments by the farm's manager. The photograph was taken after the 1991 harvest.

We grow Ethiopian barley at our experimental farm in the northern mountains of New Mexico. We grow it for three main reasons: it matures quickly (about 110 days); it is hull-less; and it is the most drought-tolerant grain we've ever had. In addition, it has been almost trouble free. We've never experienced a problem with lodging. The plant tillers very well and produces good yields in most years. We haven't had any problems with disease, which might be only because our farm is isolated and the nearest barley grower is about 50 km away.

We thresh the dry grain in a small homemade threshing machine or an old combine employed as a stationary thresher. It threshes easily. The seed is then cleaned in a seed-cleaning machine. (Both the threshing machine and the seed cleaner run off our solar electric system.) The grain mills nicely and produces a flour that has good baking and eating qualities.

Lynda S. Prim

sayings often feature this "king of grains." Everyone in the highlands encourages children to consume lots of barley. It makes them brave and courageous, they say.[8]

Ethiopians turn barley into bread, porridge, soup, beer, and many other foods. A favorite snack is roasted unripe barley seed. Several types are made into various barley-water drinks, most of them nonalcoholic.[9] These beverages (made of water infusions of roasted and ground grains) are highly valued. Also, some intoxicating liquors (*areuie*) are home brewed from barley grains.

Ethiopians draw clear associations between each grain type and its use. The white large-grained forms are preferred for porridges. The white, black, or purple large-grained types are made into bread and other baked foods. Partially naked grains are usually roasted or fried. Small-grained types (mainly black and purple) are used for beverages.

Barley is also important to the country's livestock. The grain itself is sometimes fed. (Wealthy farmers, for instance, use it to fatten horses and mules before and after long journeys or to strengthen cattle before the plowing season or going to market.) But more commonly, the animals end up eating the straw. Finely broken barley straw is also employed in constructing mud walls.

For all its importance, however, Ethiopia's barley production can be strengthened. A vast store of indigenous germplasm has yet to be tapped. Indeed, some of it is being lost. (This genetic erosion is happening mainly as farmers switch to crops such a bread wheat, tef, and recently, oats.)

Some of Ethiopia's barley could be made more useful by genes of the barleys developed elsewhere in the world. But the multitude of local types offer great opportunities on their own accounts. Many are unique. Even the number of rows of grains on the seedhead (spike) can be unique. Everywhere else in the world, barleys have exactly two rows or six rows. However, Ethiopia's irregular barley has two full rows as well as parts of other rows. And its deficient barley has two full rows, but the lateral spikelets are greatly reduced or are wanting entirely.

Although essentially unknown elsewhere, irregular barley[10] ranks fourth among Ethiopia's crops, both in quantity produced and area planted.[11] At altitudes above 2,500 m it is usually the only cereal that

[8] The ancients had similar traditions. Greeks, for example, are said to have fed much barley to gladiators. Roman gladiators were called "hordearii" in the belief that barley was the source of their strength.

[9] A popular trail food is roasted and ground barley. The traveler can stop at any stream, stir the powder into a cup or gourd of water, and have "instant barley water."

[10] It is also known as Abyssinian intermediate barley. It occurs also in Yemen, Arabia, and Egypt, but only as a very minor crop.

[11] Hailu and Pinto, 1977.

THOROUGHLY MODERN MILLETS

Whereas today's most reliable approach to advancing little-known grains is conventional plant breeding, biotechnology might soon be able to leapfrog much of the tedious and time-consuming toil traditionally involved in creating new varieties. Here we identify a few possibilities.

Because they are well known in scientifically advanced countries, wheat, rice, maize, and (to a lesser extent) sorghum have benefited from high-tech research. Millets, however, remain almost exclusively resources of countries with little or no basic research capacity. Millets have therefore barely benefited from the latest instruments and techniques. Given such attention, it seems likely that they can be leapfrogged into the twenty-first century using biotechnology.

This is especially important to Africa, where the needs are so vast and diverse, the resources so few, the time so pressing, the conditions so changeable, and the priorities so uncertain that conventional plant breeding, which can take 10-12 years to perfect a new variety, may not be up to the task. Certainly, its ability to breed for genetically complex attributes such as drought tolerance is limited. Moreover, in environments such as the Sahel, where climatic variables far outweigh genetic ones, plant breeding is all but impossible to do in the normal way in field trials.

When it comes to Africa, then, biotechnology could have a huge impact. For example, breeding can be done more quickly, it can be done indoors in controlled environments, and it can be done with greater precision. Increasingly, biotechnology can deal with genetically complex traits. In sum, technologies such as tissue culture, anther culture, embryo rescue, protoplast fusion, and genetic markers are likely to bring undreamed of breakthroughs that will transform Africa's native grains.

The key to this gene revolution is to develop tissue-culture techniques for each of Africa's grains. If scientists can grow mature, fertile plants from tissues of pearl millet, finger millet, fonio, irregular barley, and tef, they will open doors to the more rapid development of these cereals. Grasses are difficult to culture—so difficult, in fact, that not long ago they were considered impossible—but rice, maize, sorghum, and vetiver have already succumbed and can be grown routinely in tissue culture. Now it seems likely that the right conditions can be discovered for the others.

Once tissue culture has been established, a major challenge will be to "map" the chromosomes using genetic "markers." Knowing the physical location of particular genes will result in many shortcuts to improved strains. This is particularly because thousands of young seedlings can be tested for the presence of specific genes, rather than waiting for the genes to express themselves in the mature plant. It will also allow desirable genes to be more easily transferred, and undesirable ones to be eliminated. The markers could be provided by the restriction-fragment length polymorphism (RFLP) technique (see box, page 34), a process already being applied to maize, barley, and rice.

Following are examples of the gains to be achieved:

Drought Resistance. Breeding drought-resistant varieties has always been difficult because researchers had no way to determine genetic influences on the basic mechanisms of drought injury and tolerance. In basic studies, biotechnology is now helping to show how water stress affects the physiological, biochemical, and molecular organization of plants during their various life stages.

In future, the new techniques could target the genes that govern rooting depth, water extraction, and root penetration of compacted soil layers. Once identified and mapped, the genes for these characteristics (which are extremely difficult to evaluate in the field) could be readily tracked in breeding programs. This would lead to crops with much higher drought tolerance.

Striga. An ability to manipulate the genes that attract or repel the striga parasite could boost cereal yields continent-wide.

Hybrids. Biotechnology would make it much easier to make hybrids within and between species. This might be brought about through chemical hybridizing agents, through clonally propagating sterile seed, or through embryo rescue.

As work progresses on the major crops in the world's most sophisticated laboratories, millets should not be overlooked. Pioneers pushing the frontiers of gene manipulation in wheat, maize, and rice, for example, should not leave the millets trailing so far behind that they will be abandoned willy-nilly. Actually, the high-tech equipment and powerful genetic tools could likely help make major advances in millets and thereby bring more humanitarian benefits than in all the rest of the work.

can be cultivated satisfactorily. It is very important throughout most of the upper highlands, for example, where it accounts for about 60 percent of the population's total plant food. Farmers in that area rely on fast-maturing types to save their families from starving during food shortages.

This is just one example of the genetic wealth to be found among Ethiopia's barleys. Other traits include:

- High yields. Some Ethiopian barleys have big and heavy kernels, some plants tiller (send up multiple shoots and seedheads) very well, and others mature quickly.
- High nutrition. Some have high levels of protein and a few are high in lysine and are thus exceptionally nutritious. They are the only known source of quality-protein barley.[12]
- Disease resistance. Several have resistance to diseases such as powdery mildew, leaf rust, net blotch, *Septoria,* scald, spot blotch, loose smut, barley yellow dwarf virus, and barley stripe mosaic virus.
- Drought resistance. Many have the ability to grow under dry conditions—a feature apparently related to deep and efficient root types.
- Tolerance to marginal soils.
- Resistance to barley shoot fly and aphids.
- Vigorous seedling establishment.

On the other hand, Ethiopia's barleys tend to blow down easily due to weak straw and tall, spindly growth. Some specimens suffer from the condition known as "fragile rachis," in which the seed spike breaks apart and spills the seeds on the ground.

The outside world's barley breeders have not neglected Ethiopia's materials. For example, they employ the accession called Jet (jetblack seeds) to obtain resistance to loose smut, a severe fungal disease. In the United States and several other countries they have employed the genes for resistance to the extremely damaging barley yellow dwarf virus, leading to great savings in grain yields. But many more useful types remain to be employed both at home and abroad.

ETHIOPIAN OATS

Ethiopia also has a native oats, *Avena abyssinica.* Partially domesticated in the distant past, this species is largely nonshattering—that is, it retains most of its grain so farmers can harvest them conveniently.

[12] See companion report, *Quality-Protein Maize.* Quality-protein barleys are rich in amino acids, such as lysine. that are vital to human nutrition and yet normally deficient in cereals. They have been called "Hi-proly" by the Danish food scientists who have studied them most. (For a list of BOSTID publications, see page 377.)

It has long been used in Ethiopia and is well adapted to the high elevations and other conditions there. It is, however, unknown elsewhere. With a rising international interest in oats this little-known species deserves research attention.

Unlike common oats (*Avena sativa*), which is a hexaploid, Ethiopian oats is a tetraploid. It is seldom grown as a solitary crop; it is almost always sown in a mixture with barley. Agriculturists may classify it as a weak-stemmed "weed," but not the farmers. They harvest the two grains together and use them mainly in mixtures. These mixtures generally end up in *injera* (the flat national bread; see last chapter), local beer (*tala*), and other products. Some are roasted and eaten as snacks.

However, some people don't appreciate Ethiopian oats because the plant is not fully domesticated and does shatter somewhat. It is also fully fertile with the weed *Avena vaviloviana,* which creates swarms of weedy hybrids that shatter a lot.[13]

Nonetheless, Ethiopian native oats deserves research attention and a chance to prove itself.

KODO MILLET

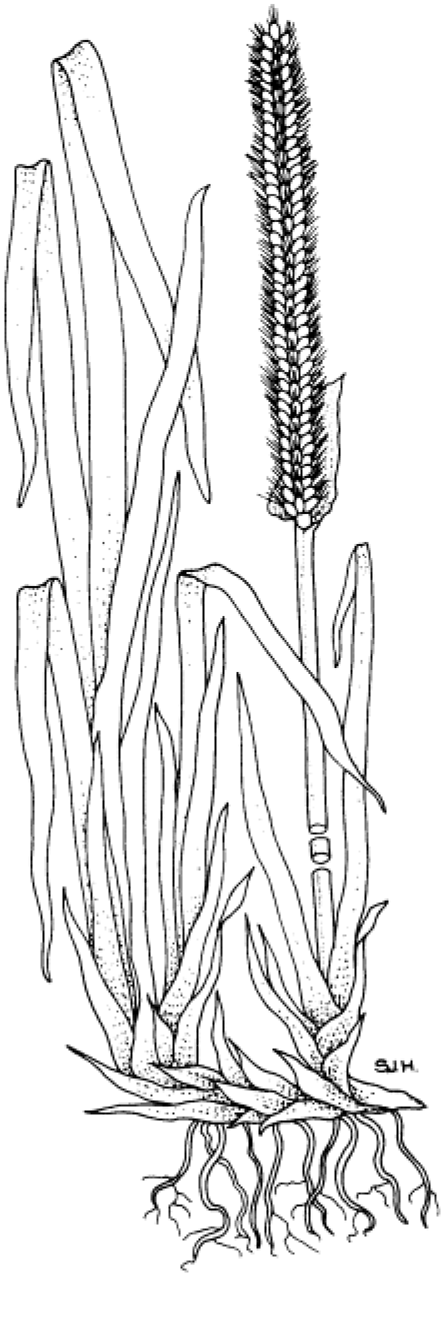
Although wild forms of kodo millet *(Paspalum scrobiculatum*) occur in Africa, the plant is not grown as a crop there. However, domesticated forms have been developed in southern India, where they are planted quite widely. This is therefore a plant in the very process of domestication, and the cultivated forms could have an important future in Africa as well.

The wild form is common across tropical Africa (as well as across wetter parts of the Asian tropics from Indonesia to Japan). It is often abundant along paths, ditches, and low spots, especially where the ground is disturbed (which accounts for the reason it is sometimes called ditch millet).

Although kodo millet frequently infests rice fields in West Africa, it is tolerated even there. Many farmers actually take pleasure in seeing it in their plots. Should the rice crop fail or do poorly, they will not have lost everything ... the field will likely end up choked with kodo millet, which can then be harvested for food. In this sense, the weed becomes a lifesaver for a subsistence-farming family.

All in all, this is another obscure cereal deserving greater modern research and recognition. Two technical problems to evaluate are an ergotlike fungal disease and the probable presence of antinutritional compounds.

[13] Specimens from these two species. as well as the hybrid between them. have also been referred to as the species *Avena barbara* Pott.. from which the Ethiopian species may have been derived.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14

Wild Grains[1]

Over large areas of Africa people once obtained their basic subsistence from wild grasses. In certain places the practice still continues—especially in drought years (see boxes, pages 258 and 264). One survey records more than 60 grass species known to be sources of food grains.[2]

Despite their widespread use and notable value for saving lives during times of distress, these wild cereals have been largely overlooked by both food scientists and plant scientists. They have been written off as "obsolete"—doomed since hunting and gathering started giving way to agriculture thousands of years ago. Certainly there has been little or no thought of developing wild grains as modern foods.

This deserves reconsideration, however. Gathering grains from grasslands is among the most sustainable organized food production systems in the world. It was common in the Stone Age[3] and has been important almost ever since, especially in Africa's drylands. For millennia people living in and about the Sahara, for instance, gathered grass seeds on a grand scale. And they continued to do so until quite recently. Early this century they were still harvesting not insignificant amounts of their food from native grasslands.

However, in previous centuries the grains of the deserts and savannas were harvested in enormous quantities. In the Sahel and Sahara, for example, a single household might collect a thousand kilos during the harvest season.[4] The seeds were piled in warehouses by the ton and shipped out of the region by the caravan-load. It was a major enterprise and a substantial export from an area that now has no equivalent and is often destitute.

[1] Much of this chapter is based on a review by Jack Harlan (Harlan, 1989).

[2] Jardin, 1967.

[3] Many of the stone (Mesolithic) implements found in archeological sites throughout the Sahara were probably created for harvesting wild grass seeds. Some are still used. Modern desert dwellers, for example, find it convenient to employ ancient grindstones they find at archeological sites instead of carrying their own from camp to camp. Information from J. Harlan.

[4] Nicolaisen, 1963.

HOW THE MILLETS AROSE

It is not illogical to think that at least some of the wild grasses in this chapter might be turned into tractable crops for farm fields and household gardens. It has been done in the past . . . by our Stone Age forebears, no less.

Between 12,000 and 6000 B.C., most of the Sahara appears to have been perfectly hospitable to humans. What is today the world's most fearsome desert then enjoyed a mild climate, winter rainfall, and an extensive grass cover. Acacia and tamarisk trees lined the many water courses. Mountainsides were verdant woodlands of myrtle, oak, hackberry, and olive, with juniper and pines at the upper altitudes.*

By 10,000 B.C. people inhabited the area. A scattering of Neolithic (New Stone Age) sites across the central Sahara provide evidence that they were using sickles and grinding equipment, which suggests that they were using the grasses. By 6000 B.C. the central Sahara people were definitely collecting wild grain as well as apparently hunting wildlife and herding livestock. The vast grasslands provided game as well as limitless grazing for cattle, sheep, and goats. Shallow lakes—occupying wide, flat pans—enlarged during the rains and provided plentiful food from fish, hippopotamus, and aquatic plants, including African rice.

But then, after about 4000 B.C., the region began drying out. The desert as we know it today had begun to form. Few archeological sites from this period are found, and the people apparently had been forced to leave.

But before they left, they had time to domesticate some of the grasses around them during the thousands of years the rather sedentary, herding-fishing-hunting people occupied the Sahara. Several cereals seem to have arisen there. African rice, fonio, pearl millet, sorghum, and perhaps finger millet got their start this way.

Those ancients did a miraculous job, considering they had no knowledge of genetics, microorganisms, chemistry, nutrition, or the myriad other sciences we now consider vital for domesticating and developing crops. Nor did they have ready access to the variety of germplasm that any scientist today would demand. If they could do it, surely we can.

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* All this is suggested by numerous pollen samples dug up in the Tibesti and Haggar massifs in the heart of the Sahara.

But in modern times these wild grains have been neglected and even much maligned. Various writers repeatedly refer to them as "famine foods." This is obviously wrong. Where the grains were gathered, surplus was often the rule. Wild grains were eaten even when pearl millet was in oversupply, for instance.

Modern writings also imply that the wild-grass grains were eaten only in desperation when nothing else was available. This, too, is apparently false. The harvest was large scale, sophisticated, and commercial: it must have been founded upon a keen and constant demand. Indeed, all evidence suggests that the grains were a delicacy that even the wealthier classes considered a luxury.

Remnants of this once vast and highly organized production still linger. One observer pointed out that harvests of wild grains were still being carried out in 1968, at least 60 years after they had last been major contributors to the local diet.[5] However, despite its former prestige and ancient heritage, the wild-grain harvest has been declining for a century or more.

A major reason for the decline is that the once vast stands of grasses are much reduced. Partly this results from the demise of the nomads. Sedentary life encourages continuous and localized grazing so that the plants never get a chance to form grains. Partly, too, the decline results from the breakdown of traditional authority. Formerly, chieftains banned grazing animals from certain areas while the wild grains were filling out. If camels were caught there during that time, the chieftain could slaughter one of them in recompense; if goats were caught, he could kill as many as 10.

Just because wild grasses no longer contribute greatly to Africa's food does not mean they should be disregarded. Even preliminary study is likely to turn up many fascinating possibilities and perhaps much future potential. Many come from locations where burning temperatures, scant rains, and ravenous insects make the better-known grains impossible to produce. Some can populate and stabilize sand dunes—perhaps even the juggernaut dunes that threaten to bury oases, farms, villages, roads, and towns. Forged upon the unforgiving anvil of survival, these wild grasses are clearly suited to the worst of conditions.

In fact, plants like these—inured to harshness and constantly pressured by pathogens, pests, severe weather, and harsh soils—are just the sort of resources the world needs for overcoming some of its most intractable environmental problems. For example, some of Africa's wild cereals might be especially good weapons for combating desertification. Indeed, resurrecting the ancient grain-gathering industry could well be a way to defeat land degradation across the worst

[5] Gast, 1968.

Northern Aïr, Niger. Relict stand of wild sorghum that is harvested for grain each year. All over Africa, stands like this one are relied upon to provide food, especially during times of crop failure. (John Newby, WWF)

afflicted areas of the Sahel and its neighboring regions. A vast and vigorous grain-gathering enterprise, for instance, would ensure that once again the grass cover is kept in place and that overgrazing is controlled once more.

Such a possibility is not inconceivable. Wild cereals might be made into an everyday food source, a famine reserve, and perhaps even a specialty export crop. This last may seem unlikely, but it should at least be considered. Today, the overall situation is different from that of a century ago. Railroads and airfreight mean that grains can now be shipped from the Sahara with much greater ease than on the backs of camels. Moreover, consumers in affluent nations are increasingly interested in buying and trying "exotic" cuisines. And many people of goodwill are highly motivated and eager to help avoid the horrendous tragedies of Sahelian drought and famine they have witnessed on their television screens in recent decades.

A similar concept is being attempted as a way to combat the destruction of tropical rainforests. In the last few years, for instance, an international trade in special tropical-forest products has begun. The object is to foster an economy based on resources of the rainforest itself. If successful, it will generate powerful local disincentives for destroying the natural environment.

In the case of the rainforest, the products are such things as wild rubber, fruits, nuts, and vegetable-ivory buttons. In the case of Africa's desertifying areas, the product might be kreb.

Kreb is perhaps the most famous food of the Sahara. A complex of a dozen or more different wild grains, it was harvested from natural meadows. Its composition varied from place to place and probably from year to year, depending on the mix of grasses that grew.

These days, given some clever marketing, "kreb from the Sahara" might sell at premium prices in Europe, North Africa, and North America, for example. It would be seen as a gourmet food that provides income to nomads and protects the earth's most fragile lands from further destruction by keeping a cover of wild native grasses on them.

Although this idea is highly speculative, subject to many limitations and uncertainties, it is not beyond reason. Mixed-grain products are not uncommon in Western supermarkets these days. For instance, in the United States a popular breakfast cereal is a grain mixture that people boil in water like rice. (It is made from conventional grains but goes by the trade name "Kashi," another word for kreb.[6]) And some expensive breads are made from as many as 11 different grains.

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[6] The pamphlet in each box explains: "Kashi, the breakfast pilaf, is a specially formulated pure blend of whole oats, long grain brown rice, whole rye, triticale, hard red winter wheat, raw buckwheat, slightly hulled barley, and mechanically dehulled sesame seeds; 100 percent quality whole grains that are not cut, cracked, rolled or flaked nor creamy or mushy when cooked."

Resurrecting the production of kreb could provide food, income, and perhaps a protection against famine. It might bring substantial environmental benefits as well. Many of the wild African grains come from perennial grasses that continuously cover the soil and protect it from water and wind erosion. In addition, these plants facilitate the infiltration of rainfall and prevent rapid runoff from desert downpours early in the season, a time when annuals are still getting started and much of the soil around them is exposed and hard. Moreover, perennial crops have long growing seasons and the extra solar energy they collect normally produces good grain yields. (This is why some hybrids, including maize hybrids, have been so productive.)

Native perennials might prove to have economic benefits as well. Perennials save the vast amount of energy and labor that farmers must put in each year to move soil for planting and tilling annual cereals. Also, they save on the often large amount of grains that must be put aside each year for planting—with a perennial, those can be eaten.

Beyond their direct use as cereals, Africa's wild grasses may also have international value as genetic resources. Some are related to species used elsewhere for food or fodder and are likely to have genes of international importance—particularly because many of them have outstanding tolerance and resistance to heat, drought, drifting sand, and disease. On the other hand, some might prove weedy when taken out of the desert and introduced to more salubrious situations.

The nutritional value of wild-grass seeds has seldom been studied in detail, but those analyses that have been made indicate that protein contents are usually considerably higher than that of cultivated cereals. Several Saharan grains, for instance, have protein contents of 17-21 percent, roughly twice that of today's main cultivated cereals.[7]

All cereals are low in vitamins A, D, C, B, and the amino acids lysine and tryptophan. Wild grass seeds are no exception. However. some may be unusually high in food energy. Certain kram-kram seeds, for instance, apparently have about 9 percent fat and are perhaps higher in energy than any other cereal grain.[8]

Africa's promising wild cereals include those described below. All of these deserve the attention of food and agricultural scientists, as well as of the people involved in battling Sahelian desertification. Even the most basic studies could be extremely valuable. These include the following:

- Tests to determine how best to plant and establish each species (seed treatments, sowing depths, planting times, and so on);

[7] Busson, 1965. Much of the difference may be due to their small seed size. Domesticated grains are usually bigger, and the increase is primarily due to endosperm, which is largely starch.

[8] Busson. 1965.

HARVESTING WILD GRASSES

To most people, it probably seems inconceivable that in this age of intensive agriculture, wild grasses are still being gathered. The following (*adapted from a recent FAO report*) *gives a sense of the ongoing importance of wild grains in different parts of Africa.*

Niger

On their way from the wet- to the dry-season pastures, the Tuareg of Niger regularly harvest wild cereals. The grains, collectively known as *ishiban,* include desert panic (*Panicum laetum*) and shama millet (*Echinochloa colona*). Women do most of the gathering, and around harvest time groups of five or six women often go off for a week or so to gather wild grains (as well as fruits, gum arabic, and other wild products).

They collect the grains in different ways:

- If the seed is ripe and ready to fall, they harvest early in the morning when dew tends to hold the seed in the inflorescence. They swing a deep, cone-shaped basket through the tops of the plants to gather the grain.
- If the seed is not ripe enough to fall, they first cut the grass and then dry, thresh, and winnow the grain as if it were a domesticated cereal
- If the seed has already ripened and fallen, they cut or burn the stands, and later sweep the seeds up off the ground. (This spoils the taste and adds soil and pebbles, but the harvesters often have no choice.)
- Sometimes the women search for seeds in ant nests and termite mounds. In desperate times, such as the terrible drought of the 1970s, they even dig down to the ants' subterranean storehouses.

Sudan

The Zaghawa of the Sudan and Chad harvest many annual grasses for food and beer. These include Egyptian grass (*Dactyloctenium aegyptium*), desert panic, shama millet, wild tef (*Eragrostis pilosa*), and wild rice (*Oryza breviligulata*). Kram-kram (*Cenchrus biflorus*) and *Tribulus terrestris* seeds are used only during famine. The women generally use the grains for their own

families, but they sell some as well. The Zaghawa spend a month or two in the areas where the wild cereals grow, often returning with three or four camel loads of grain. The various sites are visited several times, at intervals of 15-30 days. The earliest harvests usually yield the most. There is much communal cooperation. The women mentally mark off areas for themselves, cut the grass, and pile it up to dry. To foil any goats or wildlife, they cover their piles with thorny branches, and to guard against theft, they leave a symbolic stone representing each woman's clan. Livestock are barred from these areas until after the grain harvest, and herders are fined if any animals get in. It appears that the gathering actually helps maintain a good stand of wild cereals, because less useful plants (especially kram-kram) are taking over the areas where gathering is no longer practiced.

Zambia

The Tonga of Zambia routinely harvest the grains of wild sorghum and Egyptian grass, and during famines they also harvest species of *Brachiaria, Panicum, Echinochloa, Rottboellia,* and *Urochloa.* They supplement these wild cereals with relishes made from leaves, most of which they also usually find in the wild. These two together provide them with sources of starch, proteins, fats, vitamins, and minerals. They also use wild native plants for brooms, building material, fiber, salt, medicine, poisons, and so on.

South Africa

When in the 1930s the Chamber of Mines began asking about edible wild plants, its labor-recruitment offices across South Africa became overwhelmed. "We were inundated with parcels from many parts of the country containing plants or parts of plants," wrote one of the participants recently. "It became clear that a nutritionally significant part of the people's diet was being obtained from the veld."

Among the grains sent in werethose from

- *Sporobolus fimbriatus* (matolo-a-maholo)
- *Brachiaria brizantha* (bread grass, long-seed millet)
- *Echinochloa stagnina* (bourgou)
- *Panicum subalbidum* (manna grass)
- *Stenotaphrum dimidiatum* (dogtooth grass)

- Direct seeding trials using rain as the sole source of moisture;
- Searches for elite specimens (those that, for instance, hold onto the ripe seed, that have bigger seed, and that best survive harsh conditions);
- Trials on various sites (from the most favorable locations to moving sand dunes);
- Analyses of food value (physical, chemical, and nutritional) as well as of the foods prepared from them; and
- Multiplication of seeds or other planting materials for distribution to nomads, farmers, governments, and researchers.

DRINN

The grass known in Arabic as *drinn (Aristida pungens)* once provided by far the most important wild grain of the northern Sahara.[9] It was extremely abundant, often growing on sand dunes but especially on bottomlands watered by runoff from higher ground. It is a tall (to 1.5 m), tufted perennial with deep roots and long leaves. Its grains are black.

Travelers crossing the Sahara in the past often wrote about drinn's value, both as a food and as forage. Duveyrier (1864) commented: "its grain is often the only food for people." Cortier (1908) referred several times to the abundance of drinn: "The hillocks of sand in all the plain," he wrote, "are embossed by enormous tufts of drinn, whose black grains at the tips of long stems swing and sweep the soil."

Even as recently as 1969, drinn was still a significant part of the diet in the Sahara oases.[10] In earlier times it was an important food from the desert's edge almost to the Ahaggar (southern Algeria). It was, for instance, vital to people living a tenuous existence in the very heart of this fearsome region; the Toubou of Tibesti (northern Chad) are just one example.[11] In fact, this grass was so crucial to life that desert tribes were characterized as those who cultivated cereals (the Mahboud), and those who gathered drinn (the Maloul).

Drinn is extremely drought resistant. It grows, for instance, between Touggourt and El Oued in Algeria on sand dunes where the average rainfall is less than 70 mm per year.[12]

PANIC GRASSES

Various *Panicum* species have been favored by grain gatherers the world over. *Panicum miliaceum* was once so popular in Europe that

[9] It is also known as *toulloult* or *loul.*
[10] Champault, 1969.
[11] Chapelle, 1958.
[12] Information from P. Beckman.

it became a crop that perhaps predates wheat. Today this plant is grown extensively in the Soviet Union and Central Asia under the name proso millet.

At least seven wild *Panicum* species are gathered for food in Africa.[13] The most important are discussed below.

Panicum turgidum

Called *afezu* or *merkba* (Arabic), this grass produces seed that closely resembles proso millet. It was once abundant across the Sahara as well as in desert lands as far east as Pakistan. It was widespread, for example, in Senegal, Mauritania, Morocco, Egypt, and Somalia and was the primary wild grass in a vast belt across the southern Sahara. Its grain was formerly gathered in large amounts, and even today it is still harvested, at least to some extent, throughout the plant's range.

This desert species grows where few crops can. It is extremely drought tolerant, thriving in dry sands in semiarid or arid areas with annual rainfalls from 250 mm down to as little as 30 mm. It is also found in semidesert shrublands and is common among the vegetation inhabiting dried-up wadis.

A deep-rooted, clump-forming perennial, this plant forms loose tussocks I m or so in diameter. It spreads by long, looping stolons, building up mats of vegetation that are extremely useful for erosion control. (Its stems fall over and root at the nodes, clamping down the soil.) It is known to colonize wind-blown sand dunes (often while they are still moving) and can protect steep slopes. The root system is extensive, penetrating to below I m as well as radiating out horizontally more than 3.4 m in plants excavated in Somalia.

Although *afezu's* main nonfood use is as a sand-binder, it provides some grazing for camels, goats, and other animals. Its palatability is generally low, but its ability to grow in virtual desert conditions, together with its perennial nature, gives it great value.

This plant bears its seeds on panicles that rise above the mat. They can be easily collected by holding the seedheads over a bowl and beating them with a stick. Most of the grain collected ends up in a porridge (*tébik*).

Panicum laetum

The grain of this particular panic grass is regarded as a special delicacy. It was an important ingredient in kreb. People still collect it for food in many parts of West Africa, sometimes on a large enough scale that it shows up in local markets. The grains are normally crushed and eaten as a porridge.

This plant, which also occurs in massive stands, ranges from Mauritania to the Sudan and Tanzania. It is an annual, often common

[13] Jardin, 1967.

on black-clay soil in areas that are seasonally flooded. Animals like it, and it is especially well suited for making hay or silage. It is not highly drought tolerant, however.

Because it occurs in almost pure stands, the grain is fairly easy to collect. People sweep a small bowl or calabash through the seedheads during the period when the ripe grains are ready to fall.

Panicum anabaptistum

Little has been written about this species. However, its grains are also eaten in at least a few parts of Africa. It, too, is liked by animals and can be utilized for hay and silage. The plant prefers heavy soils and is found predominantly on wet sites. It continues producing green shoots well into the dry season, a valuable feature in any desert forage. People weave its long, dried culms (stems) into mats for their houses.

Panicum stagninum

This interesting perennial (also known as *Panicum burgii)* is found throughout much of tropical Africa, especially the Sudan and Central Africa. Instead of producing a useful grain, it yields a thick syrup, which is used in confections and sweet beverages that are widely enjoyed in Timbuktu and other places.

KRAM-KRAM

Along the southern fringes of the Sahara the primary wild cereal is kram-kram (*Cenchrus biflorus*).[14] This annual grass builds massive stands over thousands of hectares of sand plains and stabilized dunes. In earlier times, it was the dominant cereal of both the Sahel and the borderland between the Sahel and the Sahara. In those days it was a more important food than pearl millet, and its grains were milled into flour and made into porridge on a vast scale. As noted earlier, some kram-kram seeds contain 9 percent fat and have perhaps the highest food energy of any cereal. They also have a notably high protein content—21 percent in one recent analysis, or about twice the level found in normal wheat or maize.

Kram-kram[15] is now harvested only when other crops fail, but given some attention it might once again become a universal food for the peoples of the northern Sahel. Also, this wild plant might be converted to a useful crop. Domestication could come about quickly, particularly if its grain were enlarged by selection or cross-breeding with other Cenchrus species. The plant grows well on sandy soils. It is a reliable

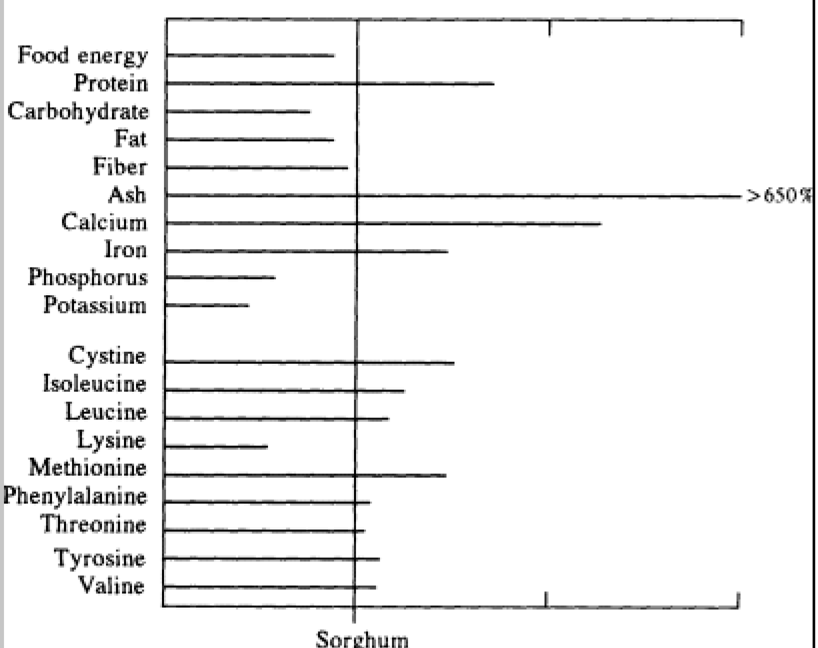
[14] In older literature this is referred to as *Cenchrus catharticus* Delile.
[15] Other common names are "Sahelian sandbur," *chevral,* and *karindja.* Tuareg names include *karengia, wujjeg,* and u*zack.*

KRAM-KRAM

Main Components[a]		Essential Amino Acids	
Food energy (Kc)	325	Cystine	1.7
Protein (g)	19.2	Isoleucine	4.8
Carbohydrate (g)	56	Leucine	15.5
Fat (g)	2.9	Lysine	1.1
Fiber (g)	2.3	Methionine	2.2
Ash (g)	10.2	Phenylalanine	5.2
Calcium (mg)	63	Threonine	3.2
Copper (mg)	0.5	Tyrosine	3.2
Iron (mg)	6.4	Valine	5.5
Magnesium (mg)	63		
Manganese (mg)	2.0		
Phosphorus (mg)	162		
Potassium (mg)	153		
Zinc (mg)	5		

[a] Assuming 10 percent moisture.

COMPARATIVE QUALITY



LAKES OF GRASS

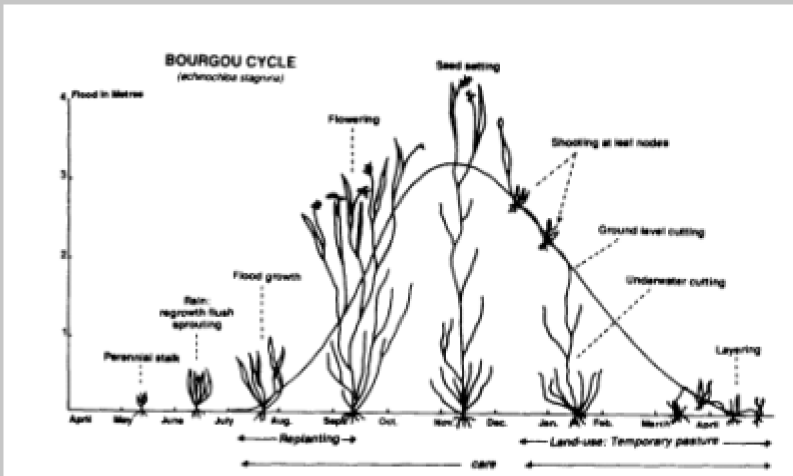
*The following, taken from a 1990 report from the United Nations Sudano-Sahelian Office (UNSO), shows how a farsighted project is restoring one of the formerly important West African wild grasses. Although it emphasizes animal feed, it gives a glimpse of what could be done by developing wild grasses for food**

To farmers and pastoralists in the Inner Delta of Mali, the bourgou floodplains supply a crucial source of fodder. Without these *bourgoutières,* the livestock would die during the dry season. Only bourgou can survive in these bottomlands that go underwater each year for months at a time.

Bourgou is unique in its adaptation to these amazing conditions. As the waters rise around it, the grass grows taller and taller until (after about 3 months) its stems can reach lengths of more than 3 m. At this point bourgou is like an aquatic plant with only its flowers and seedheads sticking above the surface. Once the water level drops, cattle are given access, and as they walk through the shallows, they trample the seeds and runners into the soft ground. This ensures that the crop will survive and grow again. However, when everything has dried out, there remains on the surface a dense mat of grass, half-a-meter thick.

This mat is what is used for fodder. If well managed, bourgou produces nearly 30 tons of dry matter per hectare—a sizable yield even for much more productive locations. When cut and

Bourgou harvest. (UN Sudano-Sahelian Office)



sold in the market, the grass fetches good prices: between 25 and 100 CFA francs per bundle (1-3 kg) in the early 1990s. The problem, however, is that the period of intense drought, from 1968 to 1985, destroyed many *bourgoutières.* So, in 1982 UNSO and the Malian government began a project to learn how to regenerate bourgou grasslands.

So far, the most effective technique has been to plant rootlings: small, rooted cuttings collected either from existing *bourgoutières* or from nurseries specifically set up for the purpose. The planting (at an average rate of 10,000 plants per hectare) is done by hand. This takes a lot of work, but it has been so successful that this grass has now been re-established on more than 4,000 hectares. And, as bourgou is a perennial, it should continue in those floodplains for decades.

Already, regenerated *bourgoutières* have had a great impact locally. Farmers use the grass both for direct grazing and for making silage and hay. Many have been able to increase their incomes through selling both fodder and milk. Local milk supplies have increased so much that thousands of families have benefited from better nutrition.

UNSO feels that areas all along the Niger River could also be planted with bourgou. It is possible that the grass might even thrive in other river valleys, such as that of the Senegal, where annual floods make better known crops difficult to grow.

* For more information, contact United Nations Sudano-Sahelian Office (UNSO), Avenue Dimdolobsom (section 3), B.P. 366, Ouagadougou, Burkina Faso.

source of forage, since it persists in a dry but palatable state until the next rainy period.[16]

On the other hand, kram-kram is vicious. It is a sandbur whose grains are enclosed in clusters (fascicles) surrounded with many sharp spines. These grab onto the fur of animals and the clothing of people. Indeed, they easily penetrate flesh and have literally been thorns in people's sides for millennia. Travelers have long complained of the plant's "troublesome nature" and "constant inconvenience," but they did admit that it was also very useful. "Many of the Tawarek, from Bornu as far as Timbuktu," wrote Heinrich Barth in the mid-1800s, "subsist more or less upon its seed."

When mature, the burs fall to the sand in great quantities, often clinging together in giant masses that roll along with the wind, growing as they go. People sweep them up with bunches of straw or with giant "combs." They throw them into a wooden mortar and pound and winnow away the troublesome spines, leaving behind the white, flavorful seeds.

Livestock cannot abide the prickly spikelets, but they like grazing on kram-kram both in its juvenile state and after the spiky burs have fallen off. The plant grows vigorously, and during the rainy period it can be cut several times for hay or silage. The hay must be made at times when the burs are absent, but silage can be made at any time because the fermentation softens the bristles, so that animals digest them without difficulty.

Not all forms of this plant are spiky nuisances. At least one has blunt inner spines and no outer spines at all. It has been called *Cenchrus leptacanthus.* If this type breeds true and if it could be developed as a crop, it would make kram-kram easier to handle and perhaps very valuable as a forage for many dry areas.[17]

A related species, also used as a wild cereal, is *Cenchrus prieurii.* It is spread throughout the Sahara from Senegal to Ethiopia (as well as India). People eat the crushed grain, mainly as porridge.

BOURGOU

Of all the grasses of the central delta of the Niger, bourgou (*Echinochloa stagnina*) was once the most prevalent. At one time it covered an estimated 250,000 hectares. (Much of that land, which is

[16] Information from R. Bartha.

[17] A close relative. *Cenchrus ciliaris* (commonly known as "buffel grass"), is a perennial with a very high forage value. It is increasingly used throughout the world's tropics and subtropics.

flooded for part of each year, is now under cultivated rice, see Chapter 1.) The Fulani people, for example, harvested large amounts of bourgou seed for food. They also got sugar from the plant. Some of the sugar produced by photosynthesis is not converted to starch and accumulates in the stems. People used it in beverages, both alcoholic and nonalcoholic. Even today, some sugar is still extracted from bourgou and is utilized especially for making sweetmeats and a liqueur.

This grass is found typically along river banks and other moist areas, especially those of Central Africa and on the central delta of the Niger. Recently, a farsighted UN-sponsored project has begun to restore some of the old bourgou stands in the area (see box, page 264).

Although its seeds are harvested for food, bourgou today is mainly used for fodder. For this purpose, it is notably important at the beginning of the dry season. As the annual floodwaters recede, it provides the vital forage needed to fatten livestock before the dry season sets in and their drastic weight losses begin.

The genus *Echinochloa* is one of the larger ones in the grass family. Two more species used for food in Africa are the following.

Antelope grass (Echinochloa pyramidalis)

This native of tropical Africa, southern Africa, and Madagascar is primarily used for fodder, but is also used locally as flour.

Shama millet (Echinochloa colona)

This plant probably originated in Asia, but it has been in Africa a very long time. Today people eat its grain only in dry years, although Egyptians possibly once grew it as a cereal on farms. The plant thrives in wet, clay soils where few grasses do well (in some African languages it is called "waterstraw"). Beyond its use as a food, the plant is suitable for making hay and silage and is relished by livestock.

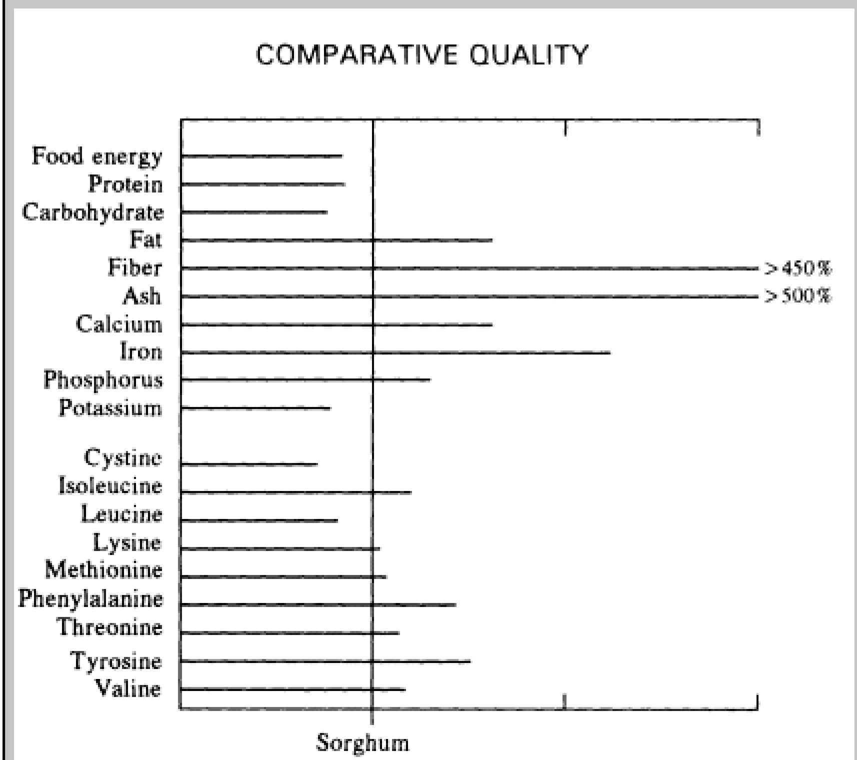
CROWFOOT GRASSES

At least one *Dactyloctenium* species is eaten in Africa. It is the so-called Egyptian grass (*Dactyloctenium aegyptium*). This annual of the Sahara and the Sudan is now widely naturalized in different parts of the tropics and subtropics, including North America. It has never been considered as a possible cultivated crop, but nomads and others in its homeland (as well as Australian aborigines) gather the grains for food. The plant mostly grows in heavy soils at damp sites below 1,500 m. Livestock enjoy it, and it is also suitable for making hay and silage.

SHAMA MILLET

Main Components[a]		Essential Amino Acids	
Food energy (Kc)	311	Cystine	0.8
Protein (g)	9.5	Isoleucine	4.6
Carbohydrate (g)	56	Leucine	10.8
Fat (g)	5.3	Lysine	2.1
Fiber (g)	11.1	Methionine	1.6
Ash (g)	7.8	Phenylalanine	6.9
Calcium (mg)	45	Threonine	3.5
Copper (mg)	0.4	Tyrosine	4.3
Iron (mg)	9.7	Valine	5.8
Magnesium (mg)	198		
Manganese (mg)	2.5		
Phosphorus (mg)	369		
Potassium (mg)	270		
Sodium (mg)	9		

[a] Assuming 10 percent moisture.

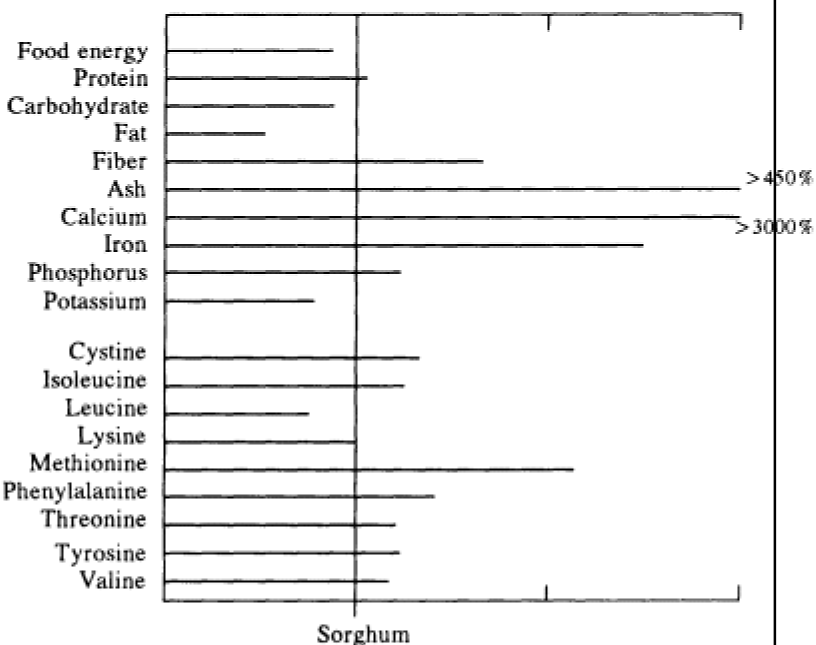


EGYPTIAN GRASS

Main Components[a]		Essential Amino Acids	
Food energy (Kc)	323	Cystine	1.5
Protein (g)	11.8	Isoleucine	4.8
Carbohydrate (g)	65	Leucine	9.9
Fat (g)	1.7	Lysine	2.0
Fiber (g)	4.0	Methionine	3.2
Ash (g)	7.5	Phenylalanine	6.8
Calcium (mg)	963	Threonine	3.5
Copper (mg)	0.6	Tyrosine	3.7
Iron (mg)	10.9	Valine	5.8
Magnesium (mg)	198		
Manganese (mg)	38.3		
Phosphorus (mg)	351		
Potassium (mg)	270		
Zinc (mg)	6		

[a] Assuming 10 percent moisture.

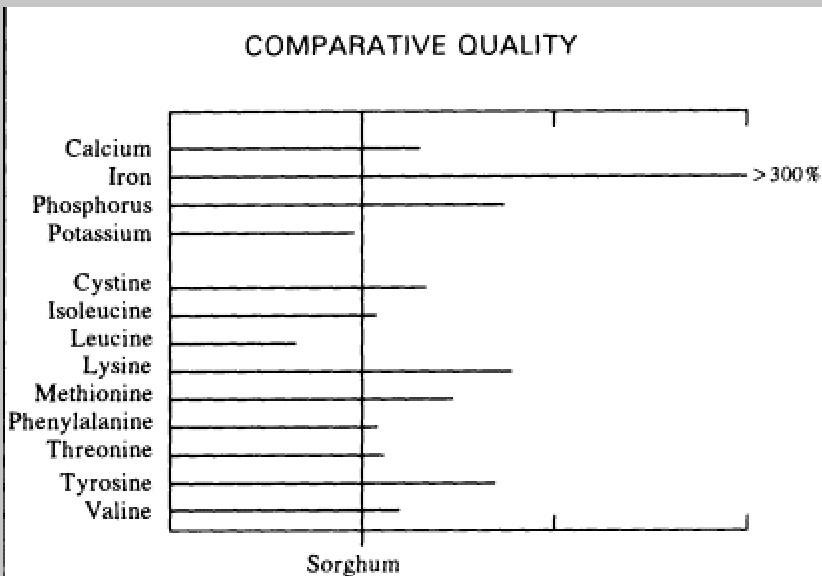
COMPARATIVE QUALITY



WADI RICE

Main Components[a]	Essential Amino Acids		
Calcium (mg)	36	Cystine	1.5
Copper (mg)	0.6	Isoleucine	4.1
Iron (mg)	15.1	Leucine	8.6
Magnesium (mg)	243	Lysine	3.6
Manganese (mg)	4.4	Methionine	2.2
Phosphorus (mg)	495	Phenylalanine	5.2
Potassium (mg)	333	Threonine	3.4
Sodium (mg)	9	Tyrosine	4.8
Zinc (mg)	4	Valine	5.9

[a] Assuming 10 percent moisture.



This chapter's tables and graphs show that Africa's famine-food grains can be quite nutritious. They are notably rich in those amino acids that are essential for human health but that are normally deficient in sorghum and the other common staples. Kram-kram, Egyptian grass, and wadi rice, for example, have more of the sulfur-containing amino acids than the **FAO** reference protein requirement. Egyptian grass and shama millet proteins are also significantly higher in threonine than those usually reported for sorghum protein. Wadi rice protein (see above) is notably better than sorghum, but it closely resembles that of common cultivated rice in its amino-acid composition.

WILD RICES

Cereals of the West and Central African savannas include two wild rices. One, *Oryza barthii,* is the wild progenitor of the African domesticated rice (see African rice chapter, page 17, and especially the map, page 23). An annual, it tends to grow in shallow depressions that fill with water during the rains but later dry up. It produces abundant seed and is still harvested on a considerable scale.

The second species, *Oryza longistaminata,* is perennial and thus requires a more continuous supply of moisture. It is a relatively shy seeder, but its grain is sometimes harvested in sufficient quantities to reach the local markets.

A third wild rice (*Oryza punctata*) is indigenous to eastern Africa. This so-called "wadi rice" is a freely tillering annual that grows up to 1.5 m tall, and it, too, commonly occurs in rain-flooded depressions. Its seeds are relatively large and resemble those of cultivated rice except that they have a reddish husk. In Central Sudan, where wadi rice is widespread, the grains are boiled with water or milk and eaten as a staple.

OTHER WILD GRAINS

Among other wild African grasses that are, at least on a few occasions, used as food are the following. Little or nothing is known about these or their food uses, but certain botanical tomes contain the following cryptic comments.

Urochloa mosambicensis. Central and East Africa. Grains boiled.

Urochloa trichopus. Tropical Africa. Grains sometimes eaten.

Themeda triandra. Tropical and southern Africa. Perennial grass.

Grain eaten during times of famine. Forms principal cover in fireclimax savanna areas. Used as fodder for livestock. Possibly of use in papermaking. Used a lot for thatching; bundles are sold in Ethiopian

markets for the purpose.

Latipes senegalensis. Tropical Africa. Annual grass. Seeds are eaten by desert tribes.

Eragrostis ciliaris.[18] Widespread in tropics. Grains used as famine food.

Eragrostis gangetica. Tropical Africa and Asia. Grains used as famine food.

[18] This and the following *Eragrostis* species are related to tef (see chapter 12, page 215).

Eragrostis pilosa. Grains harvested regularly in East Africa.

Eragrostis tremula. Tropical Africa and South Asia. Grains used as famine food.

Setaria sphacelata. Eastern South Africa, South Cape, Botswana, Namibia. Perennial, robust, usually tufted grass. Of much economic importance. Different varieties or ecotypes have various uses: for hay and silage; for silage only; or just for grazing. Seeds eaten as famine food.

Appendix A

Potential Breakthroughs for Grain Farmers

This book was intended to be solely a survey of Africa's promising grains. However, in drafting it the staff became aware of certain nonbotanical developments that could bring enormous benefit to the use and productivity of Africa's indigenous grains. Some of these promising developments that deal with farming methods are presented here; others dealing with food preparation are given in Appendixes B, C, and D. It should be understood that the innovations described are not the only ones. Indeed, there may be dozens of alternatives for helping to solve the problems described. Nor is it our intention to suggest that these are panaceas. It should be understood further that the novel subjects described here are largely unproved or even undeveloped. Each incorporates a sound and seemingly powerful concept, but whether any will become truly practical in the harsh reality of rural practice and poverty is uncertain. We present them to encourage scientists and administrators to explore these unappreciated topics that just might become vital to Africa's future.

CONQUERING QUELEA

A tiny bird is perhaps the greatest biological limit to African cereal production. The most numerous and most destructive bird on earth, the seed-eating quelea (*Quelea quelea*) can descend on a farm in such numbers as to consume the entire grain crop in a matter of hours.

Quelea occurs only in Africa, but there its population is estimated to be at least 1.5 billion.[1] Although it holds much of the continent's agriculture hostage, its worst outbreaks are in parts of the eastern and southern regions, where its plagues are worse than those of any locust.

[1] One estimate puts the number as high as 100 billion.

The fields of ripe grain lying in the path of quelea migrations are essentially doomed. And it is unlikely that the consequences will diminish. Indeed, marginal lands are increasingly employed to grow grains, and future destruction is likely to be even greater.

The quelea's influence is insidious. This bird not only eats enough farm grain to feed millions of people, it destroys the farmers' morale and drains all interest in planting more land. Where quelea occurs, family members must patrol the ripening fields for weeks, disrupting their lives and restricting all outside activities such as jobs or schooling. Its preferences even dictate what is planted —millions of families now grow dark-seeded, tannin-rich, poorly digestible sorghums, at least in part because the birds, quite naturally, dislike them (see Chapter 10).

Trying to scare away hordes of ravenous birds is clearly futile in all but the smallest plots. Efforts to control quelea with poisons, napalm, dynamite, pathogens, and electronic devices have failed. Dynamiting the densest concentrations can achieve temporary local control, but a single flock may contain more than two million pairs and spread over an area far too wide for an explosion to have much effect. However, one line of research is now showing some promise.

At sunset each day queleas congregate in patches of tall grasses or trees. As the sky darkens they crowd together, until thousands are packed side by side in a small space. Researchers at the Zimbabwe Department of National Parks and Wildlife Management have observed that (provided the night is dark and the roost is isolated and fairly homogeneous, such as a patch of bulrushes) the birds are loath to leave. When disturbed, the chattering flock flutters forward a meter or two and only reluctantly decamps into the soundless darkness beyond. Indeed the scientists found that, once the flock had settled in, they could "herd" it around in the roost on moonless nights. By blowing whistles, beating on metal, or making some other disturbance, they could hustle the birds from one end to the other at will.

This was the key. If a barrier (a sheet of glass or transparent plastic, for example) was placed across the middle of the roost, thousands of queleas could be forced to fly into it each night (at least, for three consecutive nights, after which the birds became more cautious). If a holding cage was placed beneath the barrier, at least some of the half-stunned birds tumbled in. They could then be dispatched humanely, or, even better, could be trucked directly to a slaughtering facility and processed like poultry.[2]

[2] These grain-fed fowl make good food and traditionally have brought high prices in Zimbabwe. However, Zimbabwe law now prohibits eating them because 16-65 million quelea are killed each year by spraying bird toxins onto their roosts and nests. It has been noted, however that people follow the spray teams and few dead birds remain on the ground for long.

In a second step, the Zimbabwe researchers tested tailor-made roosts. In isolated locations (and on sites quelea should find irresistible), they planted plots of napier grass and shaped them with slightly narrowed waists where the barriers and traps could be easily erected.

This seemed like an excellent way to turn a pest into profit, or at least into food, but it proved to have operational difficulties. The biggest problem was that only a few birds ended up in the cages. Those coming in from the fields flew fast enough to stun themselves on the glass, but most of those herded within the roost recovered too fast to fall.

Actually, because of such disappointing results the Zimbabwean authorities dropped the whole idea. They do, however, still use trap roosts to concentrate the birds so that workers with backpack sprayers can get to them with avicides (bird-killing chemicals).[3] This is much cheaper than using aircraft.

For most parts of rural Africa, killing birds with chemicals is unlikely to be nearly as practical or as appealing as capturing them for food. Thus, even though not yet perfected, the trap-roost concept seems to have promise. Indeed, it might in the end prove ideal for much of rural Africa because it offers the hungry poor both food and source of income. In principle, the operation is simple, cheap, and easy to understand and replicate. Given a new burst of innovation, today's limitations might well be overcome. Nets might be devised or the cages raised so that the chattering flocks would fly right in during the dark of the night and not have to stun themselves at all. Certainly, there seems to be much scope for improvement.

Of course, at this early stage there are many uncertainties even if the method can be made operational. Will it work in locations where the birds normally roost in trees? Could it be modified for use in trees? Are there grasses better than napier?[4] Will the birds learn, over time, to avoid the seductive patches of grass?

These issues are of course unresolved. However, if this approach can be made to succeed even partially, its effects could be far-reaching. And if it can be brought to perfection, it might transform the production of cereals throughout the quelea combat zone. Relieved of this feathered scourge, farmers could grow the best-adapted, best-tasting, and most nutritious grains. They could plant more land, their children could stay in school during bird season, and they themselves could keep their outside jobs.

[3] Information from C. Packenham.

[4] Vetiver grass seems likely to be a more practical choice. It is a perennial that neither spreads nor is attractive to grazing animals. Trap roosts made of vetiver would stay in place, perhaps for decades. Whether the birds will roost in blocks of vetiver grass should be quickly tested. This plant is described later in the chapter.

Although the trap-roost technique will never be a panacea,[5] it appears to have advantages over other approaches on several grounds:

- Environmental. The method requires no bird-killing chemicals.
- Economic. Trap roosts need no imported materials and farmers can build them with their own labor and materials so the technique could be employed by subsistence farmers, who have no cash to spare for bird control.
- Conservation. Although the fact that other species roost with quelea is a concern that needs to be evaluated,[6] techniques such as use of chemicals and explosions, for instance—are as indiscriminate or more so.
- Logistical. The method is independent of supplies, government, consultants, or high-level training.
- Adaptability. Catching birds in trap roosts seems infinitely adaptable to various locations and to the differing needs of users from subsistence farmers to large-property owners. For instance, a village farmer might install a small trap roost to get a little "poultry" for a party or a corporate farmer may establish many large ones to maximize a crop worth millions.

EXORCISING WITCHWEED

A small plant is the second largest biological constraint on Africa's cereal production. Usually called striga or witchweed, it is a parasite that lives off other plants during its first few weeks of life. Its roots bore into neighboring roots and suck out the fluids, leaving the victims dried out and drained of life.[7]

Unfortunately, striga (there are two main species, *Striga indica* and *Striga hermonthica*) loves maize, sorghum, millet, cowpeas, and other crops. Millions of hectares of African farmland are continually threatened; hundreds of thousands are annually infested. The traditional defense was long, idle fallow-—now impossible because of population pressure.

[5] Even were it possible, eradicating quelea would not solve all bird problems because sparrows and other grain-eating species also occur.

[6] It is possible that desirable or endangered birds might inadvertently get caught, but so far experience shows that the tailor-made quelea roosts invariably contain few or no other species.

[7] Actually, striga seedlings are so small that the "drain" they put on the host is probably only moderate. However, the victim does dry out and die. It is suspected, though not proven, that striga somehow modifies the host's metabolism to interrupt its resistance to drought (thus the drying-out effect) and to increase its production of roots (at the expense of its leaf growth). Obviously both are processes that greatly reduce grain yields. Information from L.L. Riopel.

And today when striga breaks out severely, nothing can be done. Farmers usually abandon their land. Some of the most productive sites now lie idle—victims of this abominable sapsucker.

And the problem is worsening. Striga is most damaging when crops are stressed by drought or lack of nutrients—phenomena that are increasingly common. Changes in farming practices are also helping striga to conquer ever more countryside. The continuous cropping of cereals, for example, contributes more and more striga seed to the soil.

At present, the only way to keep this weed in check is by carefully crafted farming practices: crop rotations, fertilization, and skillful use of herbicides, for instance. But this is impractical for the millions of subsistence farmers who have no surplus land for crop rotations and can afford neither fertilizer nor herbicides. Also, it would be nearly impossible to train millions of farmers to modify their farming practices, especially in the impoverished zones where striga is most threatening.

A "technological fix" to take care of the problem easily, universally, and permanently has never been found, but there is a possibility that it might be just around the corner. A crack in the plant's biological armor has been discovered, and through it researchers see exciting new prospects.

The excitement is based on the recognition that striga relies heavily on "chemical signals" to locate its victims. The mechanisms of this signaling have now been defined. In addition, approaches have been designed to cut striga's "lines of communication" or to provide misinformation. And control methods are proving successful in laboratory trials and even early field experiments.

Striga seeds refuse to germinate until they receive a chemical signal from the root of a potential host. The signal telegraphs the fact that a victim is nearby and that moisture is adequate for successful germination. The seed may lie dormant for decades awaiting this chemical confirmation that it is safe to come out.

But striga's elegant adaptation provides a window of opportunity. Farmers could, at least in theory, block the signals. Better still, they could supply false signals and trigger striga seeds into suicidal germination. Striga depends so much on the lifeblood of other plants that unless its seedlings can latch onto a root within four days, they die. Each striga plant produces millions of tiny seeds, but a chemical trigger could perhaps fool all of them into germinating. If the land had been newly plowed, the parasite would find no victims and four days later farmers could safely plant their crops.

Recently, scientists have identified chemical signals that trigger striga's germination as well as others that inhibit it. Apparently, the balance between stimulation and inhibition is what determines whether

the seed will germinate. Both chemical types are extremely active. The stimulants, for instance, can be diluted 10,000-fold or more and still cause striga seed to germinate.[8]

If compounds like these can be synthesized, mimicked, or economically extracted from plant roots, they could be (at least in humanitarian terms) among the most valuable of all organic chemicals. For example, it may be possible to produce striga-suicide sprays, perhaps even in the regions that require the most help. This approach has been exploited by Robert Eplee of the U.S. Department of Agriculture to dramatically reduce striga attachment in greenhouse tests.

Also, another striga signal has been identified. This compound (2,6-dimethoxybenzoquinone) "tells" the germinating striga seedling to form the organ (haustorium) that pierces the victim's root. This, too, may offer a way to overcome striga. For instance, an antagonist chemical might blunt striga's underground weapon. If the pest can find no host, it never develops a growing shoot (apical meristem), it never becomes photosynthetic, and it dies.[9]

Recently, scientists have found that nature is ahead of them. At least one strain of sorghum can already foil striga by producing water-soluble compounds that are striga inhibitors. This sorghum, SRN-39, both resists the parasite and has desirable agronomic characteristics and good-quality grain. Its striga resistance appears to be simply inherited (only one or two genes). Crosses with other cultivars have already been made and promising progeny obtained. Moreover, an assay has been developed to screen breeding material for this resistant characteristic. These results suggest that sorghum breeders may soon be able to breed for striga resistance rapidly and efficiently.[10] Similar progress has been achieved in maize.

It has also been found that some leguminous plants—*Crotolaria* species are examples—excrete their own striga-stimulating signals but do not serve as hosts. Although the striga germinates, it immediately dies. Thus, plants like these could be employed to deplete the striga seed bank in the soil. They may prove extremely valuable species for fallow crops or alley crops. *Crotolaria* species (rattleboxes) are le

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[8] Information from L. Butler.

[9] New results suggest that striga uses a "chemical radar" approach to host detection. The striga itself releases enzymes that remove the stimulants from the root's surface. This is a novel, and very effective, means of detecting the presence of a potential host. Disruption of this enzymatic function is also being effectively exploited by the U.S. Department of Agriculture.

[10] In fact, about 10 years ago a series of SAR *(Striga asiatica* resistant) varieties that have a very high level of resistance to the white-flowered *asiatica* were developed in India. More recently, in southern Africa, five SAR lines have been found to have reasonable resistance to the red-flowered *asiatica* found in Africa. As with SRN-39. inheritance is simple. (Information from L. House.)

gumes, so they not only knock out the parasitic pest, they also enrich the soil with nitrogen and organic matter.

All these approaches to the striga problem should be top research priorities, and not only in Africa. This parasite already affects India and has broken out in a small part of the United States. It could easily come to infect much of the world's farmland. Solving the problem now would lift from African agriculture a burden so big that the result might compare with a "Green Revolution." It would also help insulate the rest of the world from the heartbreak of this herbaceous horror. All countries have a stake in the outcome of this challenging research.

LIQUIDATING LOCUSTS

Numerous African countries, but especially those in the Sahel, are victimized by the desert locust (*Schistocerca gregaria*). Controlling this one pest soaks up vast amounts of money, time, and insecticides—700,000 liters of concentrate were sprayed over 14.5 million hectares in 1988, for instance. It has generally been effective, but in recent years some of the locust's relatives have risen up to become equally menacing. In 1989, for example, grasshoppers—in particular the Senegal grasshopper (*Oedalus senegalensis*)—*arrived* just at harvest time, causing 10 times more damage than the locusts had the previous year.

For nearly 30 years Dieldrin was the pesticide of choice. Applied in strips across the desert terrain where locust larvae hatch, it seemed an ideal way to stop the insects before they reached their damaging migratory stage. It worked, it needed no repeated spraying, it was cheap, and it could be stored without degrading even in the scorching heat of the Sahara. But in the late 1980s, even while locust swarms were swelling to worrisome levels, people began protesting because of Dieldrin's potential toxicity to humans and animals.

On environmental grounds, organophosphorus chemicals and pyrethroids seemed preferable but they remain effective for a few days only and must be reapplied over and over. This means higher costs, more work, and the destruction of all insect life—even beneficial species.

Now, a new approach to chemical control seems to offer some hope. Research in Germany has shown that oil from the seed of the neem tree (*Azadirachta indica*) stops locust nymphs from clustering.[11] After exposure to even tiny doses, the juvenile locusts fail to form the

[11] Information from H. Schmutterer. This tree and its promise for controlling insects and other pests is described in the companion report *Neem: A Tree for Solving Global Problems.* (For a list of BOSTID publications, see page 377.)

massive, moving plagues. They remain alive but solitary and lethargic; they sit on the ground, almost motionless, and are thus very susceptible to insectivorous birds. Grasshopper nymphs are affected in the same way.

This is very different from the earlier applications of neem against locusts. Those first attempts used alcoholic extracts of the seed kernel, and were aimed at disrupting metamorphosis or at stopping the adults from feeding on crops. Although highly promising in experiments, they proved less successful in practice.

The new approach uses neem oil rather than neem-kernel extracts. Experiments have shown that at very low concentrations (2.5 liters per hectare) this oil, like Dieldrin, prevents locusts from developing into their migratory swarms. It doesn't kill them but it keeps them in the harmless, solitary (green) form. It apparently disrupts the formation of hormones necessary for the transformation into the yellow-and-black gregarious stage whose plagues are the bane of arid Africa and Arabia.

The neem tree grows throughout West Africa, and thus the locust-control agent could, in principle, be locally produced. To press the oil out of the neem kernels and to spray it over the areas where locusts breed and gather requires neither particularly high-technology equipment nor unexpected expense. The oil itself is neither toxic to mammals nor to birds and is biodegradable.

Another approach that may have some localized merit is to provide nesting sites for insectivorous birds. In western China, where another plague locust occurs, farmers have reportedly met with success by protecting, and even building, nesting sites for the feathered locust eaters of the area.

EASING EROSION

The effects of soil erosion are well known: it devastates farms and forests; worsens the effects of flooding; shortens the useful lifetimes of dams, canals, harbors, and irrigation projects; and pollutes wetlands and coral reefs where myriad valuable organisms breed. But there could now be a way to slow or even stop it.

Hedges of a strong, coarse grass called vetiver have restrained erodible soils for decades in Fiji and several other tropical locations. The hedges are only one plant wide and the land between them is left free for farming, forestry, or other purposes. This persistent grass has neither spread nor become a nuisance. If current experience is applicable elsewhere, vetiver offers a practical and inexpensive solution to the problem of soil losses in many locations. It could become an

exceptionally important component of land use, at least in the hot parts of the world.

This deeply rooted perennial can already be found throughout Africa, but in most places the idea of using it as a vegetative barrier to erosion is new and untested. However, it is not farfetched. Strips of vetiver certainly are able to catch and hold back soil. The stiff lower stems act as a filter that slows the movement of water enough that it drops its load of soil.

Equally important, the dense, narrow bands of grass cause the runoff water to spread out and slow down so that much of it can soak into the soil before it can rush down the slopes. This captured moisture allows crops to flourish when those in unprotected neighboring fields are lost to desiccation.

So far, all the international attention has focused on an Indian vetiver (*Vetiveria zizanioides*). This is already widespread in Africa and has shown promise for controlling erosion in Nigeria, Ethiopia, Tanzania, Malawi, and South Africa, and appears to be a blessing for many countries. However, Africa has its own native *Vetiveria* species. These are entirely untested, but they may confer similar benefits. One (*Vetiveria nigritana*) has long been used to mark out boundaries of properties in northern Nigeria, for instance,[12] and it has been employed for the same purpose in Malawi and Zambia as well.

Vetiver has many interesting and unexpected uses. Tobacco farmers in Zimbabwe report that putting a vetiver hedge around their fields keeps out creeping-grass weeds, such as kikuyu and couch. It even seems to be a good barrier to ground fires.[13]

In the Sahel, vetiver hedges may prove extremely useful as sand barriers. Winds off the Sahara often blow sand with such power that it scythes across the landscape at ankle level, cutting off young crops before they are barely beyond the seedling stage. Rows of vetiver planted on the windward side of fields could be an answer. The stiff stalks would doubtless halt the scurrying sand, providing both a windbreak and a sand trap.

Rows of vetiver planted across wadis may also make excellent water-harvesting barriers. Once planted, the barriers would be essentially permanent. The deep-rooted grass is likely to find enough soil moisture to survive even the driest seasons in most arable locations. Although the upper foliage may die back, the stiff, strong lower stalks that block the sand, soil, and water will remain. These are so coarse that not. even goats will graze them to the ground.

[12] It spreads so little that in legal disputes vetiver hedges have been officially accepted as valid property lines. At one documented site in northern Zambia. vetiver still exists in the same narrow lines that were planted 60 years ago.

[13] Vetiver and its promise are described in the companion report *Vetiver: A Thin Green Line Against Erosion.* (For a list of BOSTID publications, see page 377.)

HANDLING SMALL SEEDS

As has been noted several times, a major problem with many of Africa's grains—finger millet, fonio, and tef, for example—is that they have tiny seeds. Size alone is holding these crops back. Small seeds create many difficulties. They are hard to store and hard to handle because they pour uncontrollably through even the smallest holes. They also make the crop difficult to plant because the soil must be very finely textured (clods or clumps can overwhelm the seeds' puny energy reserves), and the seeds must be placed precisely at just the right depth. Moreover, because the emerging seedlings are small and weak, they are easily smothered by weeds.

Many innovations could probably be devised to overcome these problems; here we present several examples of seeding devices newly developed in four Third World countries. These are undoubtedly not the only innovations for planting small-seeded crops, but we present them here as guides to those who wish to help Africa's lost crops.

Cameroon

In the late 1980s, the Cameroonian Agricultural Tools Manufacturing Industry (CATMI) in Bamenda produced a seeder that, compared to traditional planting by hand, reduces planting time by 60 percent and seed requirements by 33 percent. It is not specifically for small-seeded crops but includes a simple distributer mechanism that can be adjusted to accept seeds of different sizes.[14] It is said to reliably plant the desired number of seeds at the right depth and distance apart. It is simple to handle, suitable for planting both on ridges and on flat land, durable, easy to maintain, and cheap.

In 1988, 30 prototypes were distributed to farmers and research stations for field testing. After further improvements, 300 more were produced and sent out. Various agricultural services ran information and demonstration campaigns to promote the planter. A line of credit was set up in the Northwest Province to enable small farmers to purchase one. In addition, other provinces were contacted and provided with demonstrators and seed planters.

A survey after the first planting season (1989) indicated that 97 percent of the farmers who tried the implement bought it. Not only did it make the work easier (no back pain) and speeded up planting, but it also reduced the need for hired labor and helped increase both the area farmed and the yields achieved.

[14] This work was done in cooperation with the Departments of Agricultural Engineering and Rural Socio-Economics of the University of Dschang.

Peru15

In the Andean city of Cuzco, Luis Sumar Kalinowski has created a seeder capable of handling kiwicha,[16] whose seeds are as small as sand grains. It is a simple, almost cost-free device that can sow large areas evenly and in uniform rows. It may also work well with Africa's small seeds.

One version of the Sumar seeder uses a scrap piece of plastic pipe with a foam-plastic cup taped to the end.[17] A nail is pushed gently through the bottom of the cup to leave a hole of known diameter. Another version employs a commercially available plastic end piece, which is drilled to provide the hole. In either case, seed placed in the pipe trickles out at a constant rate, and the farmer can vary the seeding density by walking faster or slower.

Indeed, by measuring the flow of seed through the hole, it is easy to calculate how fast to walk (in paces per minute, for example) to sow the desired density of seed. With a little practice, the farmer can attain an accuracy rivaling that of mechanical drills. For the method to work, however, it is important that the seeds be clean and free of straw, small stones, or other debris that could block the hole.

Tanzania18

Engineers at Morogoro have designed and developed a low-cost, hand-operated device known as the Magulu hand planter. It includes an attachment that can be fastened to a hand hoe and can be used to plant both maize and beans in a straight row. It is said that to plant a hectare of land using the Magulu hand planter takes between 18 and 27 man-hours as compared with 80 man-hours using the conventional method of planting by hand hoe.

Thailand

The Asian Institute of Technology (AIT), which is located near Bangkok, has developed a mechanical seeder that is now being popularized in many Asian countries. In one stroke, this so-called "jab seeder" makes a hole, drops a seed, and covers the site, without the operator ever having to bend over.

The seeder weighs only about 1.5 kg and costs about US$10.00 (including labor, materials, and mark-up). In Thailand, a farmer can

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[15] For more information, contact Luis Sumar Kalinowski, Centro de Investigaciones de Cultivos Andinos. Universidad Nacional Técnica del Altiplano, Avenida de la Infancia N" 440. Huanchac, Cuzco, Peru.

[16] This crop *(Amaranthus candatus).* a species of amaranth. is discussed in the companion volume *Lost Crops of the Incas.* (For a list of BOSTID publications, see page 377.)

[17] It is not necessary for the pipe to be plastic. Any tube—bamboo, cardboard, or other material—will do. However, standard household water pipe and the disposable coffee cups common in many countries fit together well. Also, the foam-type cups are easy to pierce with a nail, and they leave a clean, smooth hole. Caps with different-sized holes can be kept on hand for use with different crops.

[18] T.E. Simalenga and N. Hatibu, Department of Agricultural Engineering, Sokoine University of Agriculture, Morogoro, Tanzania.

recover the cost, in terms of labor saved, in only 5 days and on an area as little as one-fifth of a hectare. Mass production is expected to reduce the cost even further.

In Thailand's northern province of Chiang Mai, the idea has already caught on: a number of local manufacturers are producing mechanical seeders based on the AIT model.

At present, this machine is not intended specifically for small seeds. It is used mainly with soybean, rice, maize, and mungbean. But even with these crops, it brings big advantages in labor saving and yield.

In Nepal, field tests have found that—at wages of 25 rupees (US$1) a day—a farmer can recover the cost of a jab seeder by planting maize or soybean in just I hectare of land. Fifty seeders made locally by the Agricultural Tools Factory in Birganj cost US$13.50 each.

By making a less onerous and more systematic operation, the jab seeder could well increase grain-crop productivity and thereby benefit millions of Africa's grain farmers.

OTHER INNOVATIONS

Seed planters are probably the main need for small-seeded crops, but they are not the only need. Various appropriate technologies are required also for harvesting, storing, shipping, and handling tiny cereal grains. Some of these might come from techniques devised to produce ornamentals, forages, and vegetable crops, many of which also have minute seeds.[19]

Also, it is not impossible that the size of the seeds could be increased through selection and breeding. Luis Sumar has already created a simple machine for doing this in the case of kiwicha. The Sumar sorter uses a small blower and a sloping plastic pipe. The seeds are blown up the pipe and drop into different containers, depending on their weight. With it, Sumar has increased the grain size in kiwicha. He keeps only the heaviest for planting, so that over the years the crops produce seeds that are ever larger, on average. The use of such a simple, inexpensive device in Africa might dramatically benefit fonio, finger millet, and tef, to mention just three cereals.

[19] A reviewer from Oklahoma wrote us: "We have been handling small seeds in the Southern Great Plains with precision for half a century. I worked with native grass seeds myself for 25 years. Some of the seeds are smaller than tef, fonio, or finger millet. We had equipment that would mete out seed at low seeding rates very accurately and plant them with precision. Our planters, processors, and cleaners are, perhaps, too sophisticated for subsistence farmers, but modified versions are well within the capabilities of most village mechanics and blacksmiths. The technology has been available for a long time. Suggest you contact Chet Dewald, Southern Great Plains Range Research Station, 2000) 18th Street, Woodward, Oklahoma 73801."

Appendix B

Potential Breakthroughs in Grain Handling

Appendix A identified technological advances that might boost the production of indigenous African grains. Here we identify other advances that might similarly influence the methods of milling and storing those grains. These, too, are innovations that, in principle, could bring outstanding benefits continent-wide. Again, however, it should be realized that they are just a smattering of examples that caught our attention as the book was being prepared. Other cutting-edge technologies may be as good, or better.

NO MORE POUNDING

Every day of the year, perhaps 50 million Africans—most of them women and children—spend hours preparing the grain that their families will eat that day. They usually soak the grain in water, pound it with the butt end of a heavy wooden pole (pestle) to knock off the outer seed coat, winnow the beaten mixture to separate the bran, moisten the grain a second time, and finally pound it yet again to break it up into flour.

This is always a hot and disagreeable task. It limits both cereal use and life itself. Decorticating enough pearl millet for a family meal (about 2.5 kg) takes two women about 1.5 hours; converting the product into flour with a mortar and pestle requires an additional 2 hours, sometimes more. Moreover, because the flour spoils quickly and cannot be put aside for later use, it has to be done day after day, in fair weather and foul, and regardless of sickness or other indisposition.

Probably no single development could help rural Africa more than relief from this never-ending drudgery. It would recover millions of "lost" hours every year, it would improve health and family welfare,

SORGHUM AND WOMEN

Sorghum is a women's crop in Africa. To a large extent, they are its planters, cultivators, and harvesters. Through the accumulated wisdom of centuries, women have amassed information about the crop and its handling. Many are expert in distinguishing closely related varieties . . . a knowledge which men—even professional scientists—seldom attain. Only now, however, are researchers beginning to pay attention to this knowledge.

Joyce Kanyangwa is one of those. Working under the auspices of Texas Tech University, she traveled to three sorghum-growing areas of Lesotho, visiting selected households to gain a perspective on attitudes about the use of sorghum. "I was interested in finding out what might be done to expand the use of sorghum in the diet to give women more income for their labor, as well as a cheaper staple for their tables," she explains.

Her research indicates that improving sorghum use can do much to help Africa's women. "Sorghum is a woman's crop, but the market for the product is limited primarily to brewing beer for men," she notes.

Better processing methods are particularly needed. The processing and cooking of sorghum and millet takes more time than rice. Women going to work, either in the fields or in the community, have less and less time available for processing and cooking. Small-scale rural sorghum and millet processing mills, like the rice mills already available in India, could help promote the consumption of sorghum and millet.

"When sorghum is processed using a special machine, people like it," Kanyangwa says. "I'm optimistic that the crop has the potential for helping female-headed households feed their families better and for helping women make more money."

The introduction of suitable dehullers and flour mills will:

- Reduce the drudgery of women in the sorghum eating areas.
- Convert sorghum into a much more convenient grain.
- Improve the quality of sorghum products.
- Check the tendency of shifting from sorghum to other grains.
- Help develop composite flours and commercialize sorghum products.

Opposite: Ethiopia. Danakil Depression. At the entrance to her hut, over a goatskin, an Adoimara Danakil woman grinds sorghum between two stones. (Victor Englebert)

and it would make the whole continent more productive. Perhaps most important in the long run, it would secure the future of the local grains. At present, the burden of the terrible toil is causing a silent rebellion against sorghum, millet, and the other indigenous cereals.

Now an option is emerging. Small power mills can, in just a few minutes, perform the task that now absorbs so much human energy and time. Some of the most successful consist of a series of 8 or 12 grinding stones of the type used for sharpening tools. The essential component, the dehuller, was originally designed at the Prairie Regional Laboratory in Saskatoon, Canada. A small version specially sized for rural Africa has been built, field-tested, and improved at The Rural Industries Innovation Centre in Kanye, Botswana. It is powered by a small diesel engine.

Reportedly, the machines waste no more grain than hand pounding does. (Recovery rates of 85 percent have been achieved, which is 10 percent better than is normal in the village.) Also the machine-dehulled grains apparently make no detectable changes in local foods. Since they use dry grain, the dehullers are more flexible than traditional methods, and the resulting flour can be stored.

The dehuller does only half of what African women do: it takes off the seed's outer layer, leaving white, ricelike grain. A further grinding is needed to make flour or grits. To do this mechanically, a hammer mill is employed. In some cases, the dehuller and hammer mill are combined into a single unit.

Although these mechanical systems were designed primarily for processing sorghum and pearl millet, they have also proved satisfactory for fonio and food legumes such as cowpeas and pigeon peas.[1] One of the main attractions is their capacity to handle (without major adjustment) grains of widely different size.

Under a Canadian-sponsored program, different models are currently being developed or distributed for use in Senegal, the Gambia, and Zimbabwe. Mali and Niger, following Botswana's lead, are creating designs suitable for local toolmakers to build.

Mechanized processing probably has its most immediate use in cities and towns. In rural areas, people must carry their grain to the mill and then carry home their flour and bran. For them, the chore of carrying several kilograms several kilometers may be just as onerous as staying home and pounding the grain with a pole. However, there are ways to circumvent this. In Botswana, for instance, a donkey cart is being made available without charge to carry the grain and flour back and forth. (The donkey is fed on the customer's bran waste.) Also, the milling unit could conceivably be mounted on a cart and

[1] Finger millet is difficult to mill mechanically, but in India a suitable device has been perfected (see page 48).

wheeled to the customers. Thus, for example, a mobile mill might stop at various villages once a week and process the grain on the consumer's own doorsteps. A hammer mill perhaps might not work on such a system, but the dehuller alone would relieve the major and most unpleasant part of the drudgery.

All of this opens the possibility of substantially lessening the burdens that at present fall so heavily on millions of people. It will probably widen the mix of crops they grow. It could increase lifestyle options and employment opportunities by freeing women from the daily morning and evening chore of pounding grain. It may contribute dramatically to better health among women and children, provide time for more productive pursuits, create better markets for farmers, and lead to a more stable food situation for many countries.[2]

Despite the fact that people must pay to have their cereal mechanically milled, this mini-milling industry is already starting to take hold in parts of Africa. Several nations have introduced the Canadian-type mills, and support for their maintenance has quickly spread, even into remote areas. Moreover, merchants and consumers throughout Africa are showing increasing interest in buying and using flours instead of unprocessed grain. A grain revolution seems to be arising, bringing new options for farmers and consumers, as well as new possibilities for a better life in the rural areas.

GRAIN DRAIN

To worry only about grain production is not enough: what counts is the amount and quality of the food that gets into people's bodies. Today, unfortunately, much of Africa's cereal crop never gets that far—it spoils or is lost sometime after the harvest. Estimates suggest perhaps 25 percent of each year's food production is either lost or rendered unfit.[3] The reasons are clear. During handling and storage, heat and humidity foster molds and rots that ruin much grain. Insects, rodents, and birds steal enormous amounts. Most subsistence farmers store their harvest in small granaries (capacity 1.5 tons or so) and 1020 percent usually deteriorates or disappears before it can be eaten.

An obvious answer is better storage, and these days pest-proof silos built of several materials are showing much promise. Examples follow.

[2] This topic seems especially well suited to the U.S. Agency for International Development's current programs on "family issues."

[3] The exact figure is not known for certain. Some writers claim that postharvest grain losses in Africa sometimes top 40 percent, mainly due to poor processing and storage. Others say that it is less than 10 percent. Certain types of traditional stores are very effective, but a 25-percent loss is very common in government stores (partly because farmers often contribute only their poorest materials). And the losses on the farm can rise dramatically if a new variety of grain is produced.

Brick

A Zimbabwean engineer, Campbell D. Kagoro, has for years been developing a granary built of local brick.[4] His structures—known as ENDA granaries—have been installed in dry, poverty-prone areas of Zimbabwe. People there (as elsewhere in Africa) know how to manufacture baked-clay bricks. To build the silos, they lay the bricks directly on gravel-covered soil or on rock. (In some instances, wooden joists and masonry footings are used.) They cover the final structure with a waterproof thatch roof. The silos have a capacity of about 2.5 tons and may include up to five compartments for storing different products. They are equipped with air vents and are said to offer excellent protection against dampness, insects, and rodents.

Ferrocement

A form of reinforced concrete, ferrocement utilizes materials that are normally readily available—wire mesh, sand, water, and cement. It does not corrode easily and can last a lifetime.

Experience in Thailand and Ethiopia has demonstrated that ferrocement silos can be built on site relatively inexpensively, using unskilled labor and only one supervisor. In such silos, losses are less than 1 percent per year. Rodents, birds, insects, and dampness cannot get in.[5] If the bin is well constructed and its lid tightly sealed (tubing from a bicycle tire makes a useful gasket), even air cannot get in. Inside an airtight silo, the respiring grain quickly uses up the oxygen. Insects (eggs, larvae, pupae, or adults), as well as any other air-breathing organisms introduced with the grain, are then destroyed.

The possibility of putting ferrocement silos on every farm is demonstrated by a remarkable program in Thailand. There, where the concern is storing pure water rather than grain, the government has provided three ferrocement jars (each two cubic meters in size) for every family of six in rural areas. The project involved three million families and nine million jars. Each jar costs $20, but the per-capita cost—because a revolving fund of $13 million is recoverable—can be as low as 42 cents.

Heat is a basic problem with ferrocement (and most other) silos. Bins in the burning sun can warm up so much that moisture evaporates

[4] This work has been done at the Agricultural Technical and Extension Service (Agritex) in Zimbabwe. The design was developed by the Institute of Agricultural Engineering (IAE) and Agritex. ENDA-Zimbabwe (Environment, Development, Activities) has joined with Agritex to undertake a major study of the subject, with financial assistance from IDRC.

[5] Hundreds of ferrocement boats floating on the world's waterways demonstrate that this material can be watertight, but the construction must be top quality because the ferrocement is usually only a centimeter or so thick.

from the grain, collects at the top, and fosters molds or sprouting. For this reason, silos should always be located in the shade of trees or houses, sunk in the ground, or surrounded with some rough-and-ready sun shield (thatch or scraps of foamed plastic comes to mind).

Although much of the promise is for small bins for household use, ferrocement can also be used to construct large storage facilities for town or regional use. One of the most intriguing is the horizontal "sleeping silo" pioneered in Argentina (where they are used mostly for storing potatoes). These large structures are shaped like the hull of an upside-down ship half buried in the ground. Bulkheads give strength and also create separate compartments in which different products or different owners' products can be stored. Compared to the towering grain elevators now used in much of the world, the horizontal counterparts lie on the ground and require little in the way of engineering, footings, or structural reinforcing.

Mud

Recently, an airtight grain store made from clay and straw has been introduced to Sierra Leone. The silo, demonstrated by Chinese instructors brought by the UN's Food and Agriculture Organization (FAO), is simple in construction, low in cost, and has potential to significantly decrease postharvest grain losses.

The raw materials in this case consist of mud and straw, and the finished silo is roofed with boards, straw, reeds, or other waterproof materials. Its inventors are the peasants of northeast China who, from time immemorial, have built tiny mud turrets to store their household food reserves. In recent years, a national campaign to decentralize grain storage has led to this very simple and economical technique being used throughout the Chinese countryside. In fact, mud silos are now being built as large as 8 m in height and diameter, to hold 200 tons.

Ghana, too, has been testing improved mud silos.[6] Instead of ordinary mud, however, sun-dried molded mud bricks, from a locally made mold, are used for the circular wall. The top is a separately molded mud slab. The whole unit is sealed with a mixture of mud and clay, and the wall is whitewashed to maintain coolness.

Neither of these two silos requires any great expertise to construct or use.

Plastic

Researchers in Australia and the Philippines in recent years have jointly developed sealed plastic enclosures for storing grain in ware

[6] Adopted by the Ghana German Agricultural Development Project (GGADP).

houses located in the humid tropics. In 1992, a new project was begun to design a counterpart suited to the smaller-scale and outdoor needs of cooperatives, small millers, and merchants. The scientists have developed a plastic container that is rodent- and insect-proof and protects grain against the extremes of the tropical environment. It is also simple to fumigate and suitable for storing damp grain before drying. The plastic silos have been designed using the general principles already employed for storing bulk grains in Australia. Although conducted in and for the Philippines, this work seems suitable for application throughout the humid tropics.[7]

Rubber

Israel's agricultural research organization, familiarly known as the Volcani Institute, has pioneered development of simple, cheap, and easily movable grain stores with capacities up to 1,000 tons. These collapsible, tentlike structures can be taken down, trucked to a new site, and quickly reassembled—a novel feature that makes them especially useful for handling emergency food supplies and for storing excess grain from unexpectedly bountiful crops. The walls are constructed of rolls of strong wire mesh (actually weldmesh fencing material), but the grain is held within UV-resistant plastic liners. These silos are sufficiently airtight to control insect infestation without requiring pesticides. They are primarily for use in drier areas.

DRYING GRAIN

Insects and rodents are not the only grain despoilers. Insufficient drying also leads to vast amounts of damage. Dampness fosters molding, sprouting, and decay that renders grain inedible. Drying the grains before storing them is therefore vital. Techniques for doing this under Third World conditions are being devised in several parts of the world.

Sierra Leone

Farmers in six districts of Sierra Leone are replacing traditional mud floors, used for drying freshly harvested rice, with improved drying yards. This cheap and simple change keeps the grain clean, lessens the drying time, and reduces postharvest losses by more than half.

[7] This research was sponsored by the Australian Centre for International Agricultural Research (ACIAR), G.P.O. Box 1571, Canberra, A.C.T. 2601, Australia.

United States

The Food and Feed Grains Institute of Kansas State University has designed a new kind of dryer for developing country use. It has no fan or other moving parts and uses heat generated by burning weeds, rice husks, agricultural by-products, or other wastes.

This natural-convection, hot-air drying could open up new options in many areas of Africa where today the only cereals that can be grown are those that mature after the rains have ceased (when grains can be dried in the sun). In 1990, Kansas State tested its dryers under conditions of very high rainfall in Peru and Belize. Sun-drying was impractical, even impossible, but the new dryer proved very effective: rough rice was reduced from a level of 20 percent moisture to 14 percent in only about an hour. While this is too fast for everyday practice with rice, it clearly demonstrated that the dryer would perform well in the dampness of the tropical rainy season.

Thailand

The Asian Institute of Technology (AIT), near Bangkok, has developed a simple solar dryer, constructed of bamboo poles and clear plastic sheeting.[8] It can process up to one ton of rice at a time and even in the wet season can reduce the moisture content from 22 percent down to 14 percent in about 2 days. It is said to cost only around US$150 to build.

In this device, sunlight passes through a clear plastic sheet and strikes a layer of black ash (burnt rice husk) or black plastic sheet. This absorbs the solar energy, converting it into warm air. The heated air rises by natural convection through the slatted floor of the rice box, up through the grain (contained in fine wire mesh), and out a tall chimney (again fabricated from bamboo and plastic sheet).

Korea

In the early 1980s rice farmers in South Korea faced postharvest losses of about 10 percent. But now those losses have been halved, thanks to a new technology.[9] The system has been so successful that just 8 years after the project was launched, 70,000 dryers had been purchased. By 1995, half a million are expected to have been built.

[8] This work is part of a project sponsored by the International Development Research Centre of Canada.

[9] The dryer was developed jointly by the University of Hohenheim in Germany and the Korea Advanced Institute of Science and Technology (KAIST). Funds for the program were provided by the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH.

With this method, the grain is dried using a low-temperature process that mainly exploits the drying potential of ambient air. Basically, a fan blows air through grain in a silo. The process is cheap, requires little capital investment, and the silo can subsequently be used for storage purposes. To enable drying in humid weather and during the night, a small electric heater is used to heat the ambient air a few degrees.

In practice, the dryer is a room-sized brick structure, with a false floor to prevent soil moisture from seeping up. The air is uniformly distributed using wood or sheet metal air ducts, laid on this false floor. The air is pushed through the piled-up grain by a small 400-watt electric fan.

KILLING STORAGE INSECTS

The need to protect Africa's stored food from insects is particularly important these days. The larger grain borer, a Central American beetle introduced accidentally into Tanzania and West Africa, is relentlessly spreading through maize-growing areas. This voracious pest feeds on stored maize, cassava, wheat, sorghum, sweet potato, peanuts, and other foods. The destruction it causes can be devastating; in tests in Tanzania up to 34 percent of cob maize in a crib has been destroyed after only 3 months, and up to 70 percent of dried cassava after only 4 months.

Insects get into even the best silos when the grain is added. Previously, there were no cheap and effective controls for subsistence farmers to use. However, some innovations follow that might help overcome the problem.

Sunshine

Researchers in India have found that farm produce can be disinfested by "roasting" the bugs in the sun. They first wrap a square sheet of black polyethylene around two slats of wood, leaving a "mouth" at either end. After filling the resulting pouch with produce to a depth of 3 or 4 cm, they seal the ends by weighing them down with slats of wood or bags of earth. Finally, they add a covering of transparent polyethylene. This transmits sunlight through to the black inner pouch and traps the heat inside.

The inventors, T.S. Krishnamurthy and colleagues,[10] report that insects, at all stages of the life cycle, die when kept at 60°C for 10

[10] At the Central Food Technological Research Institute in Mysore, India. This work is described in *Appropriate Technology,* December 1991, p. 15.

minutes. They tested pouches of varying sizes containing several kinds of produce, including wheat, rice, pulses, and semolina. A pouch containing 40 kg of peanuts, for example, reached an internal temperature of 67°C in just 4 hours. Wheat took 6 hours to reach 61°C. No insects survived.

Neem Products

Neem (see Appendix A, page 279) is an Indian tree that has been introduced widely in Africa and now can be found from Mauritania to Mauritius. People in neem's homeland have long known that ingredients in its leaves and seeds can disrupt the lives of storage insects. For thousands of years, Indians, for example, have placed neem leaves in their grain bins to keep away troublesome bugs. Now, scientists are finding that there is technical justification for this process and commercial neem-based pesticides are already being employed in the United States.[11]

With all the neems in Africa (not to mention the new ones being planted because of the rising international enthusiasm for this tree), neem-based methods for controlling insects in grain stores are soon likely to be widely available.

Some German-sponsored research has already pioneered one approach that employs the oil extracted from neem seeds.[12] In this project, neem oil has proved effective against bruchid beetles—the prime pest of Africa's stored products. Amounts as small as 2-3 ml per kg of stored food will protect grains and legume seeds up to 6 months-long enough to overcome the critical period when bruchids and other storage insect pests are active.

In Togo, a program for teaching farmers how to protect seeds with neem has been under way for the past 15 years.[13] Now Niger, Senegal, and other nations are following suit. Neem oil imparts no bitterness to the food. In trials, people could not distinguish the seeds protected by it.

Probably in the long run, however, it will be neem leaves that are used most. This is the simple technique employed since ancient times in India. The leaves are merely added to the grain at various levels in the bin. The leaves eventually dry out, turn to powder, and (for all intents and purposes) disappear. The important thing is that bruchids, weevils, and flour beetles disappear also.

[11] See the companion report *Neem: A Tree for Solving Global Problems* for more information. For a list of BOSTID publications, see page 377.
[12] See also Appendix A. page 279.
[13] Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ).

Mineral Dusts

For some time researchers have known that certain powdery minerals can kill insects. The sharp-edged dust particles "spear" through the thin joints between the horny plates of the animal's exoskeleton. This was first recognized with diatomaceous earth, a widely available, completely safe powder that kills cockroaches almost on contact. Now scientists in Nigeria have found that a common local mineral called "trona" also works in the same way—at least on certain storage pests.

In experiments, powdered trona proved lethal to the maize weevil (*Sitophilus zeamais*), causing almost 100 percent mortality after 15 days of exposure. It also reduced the maize weevil's fecundity in grains treated with the dust.[14]

Trona, $Na_2CO_3{\cdot}NaHCO_3.2H_2O$, is a crystalline carbonate/bicarbonate that occurs naturally in several parts of Africa. It is apparently not toxic to humans and livestock. Indeed, in most African countries, rural people use it as a food additive.[15] For example, they commonly drop it into okra soups to increase the mucilaginous quality or into boiling cowpeas to reduce the cooking time. In northern Nigeria, farmers add trona to their cattle's drinking water.

Mixing trona dust with maize grains (at 1.5 percent by weight or more) killed or inhibited the biological activities of the most ubiquitous pest of stored maize, the maize weevil; but another noxious pest, the red flour beetle (*Tribolium castaneum*), was unaffected.[16]

Mineral dusts may never be fully reliable in grain-store insect control, but their permanence, low toxicity, and ready availability make them attractive possibilities for a simple, cheap, and ubiquitous answer to at least part of the massive and widespread storage losses.

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[14] L.C. Emebiri and M.I. Nwufo. 1990. Effect of Trona (Urao) on the survival and reproduction of *Sitophilus zeamais* and *Tribolium castaneum* on stored maize. *Agriculture, Ecosystems and Environment* 32:69-75. (L.C. Emebiri and M.I. Nwufo, Department of Crop Production, S.A.A.T., Federal University of Technology, Owerri, P.M.B. 1526, Nigeria.)

[15] It is known locally as *kaun*in Nigeria and *kanwe* in Ghana.

[16] A similar finding has been reported in respect to an inert diatomaceous earth, which was lethal to eight pests of stored products but was harmless to the red flour beetle. S.D. Carlson and H.J. Ball. 1962. Mode of action and insecticidal value of a diatomaceous earth as a grain protectant. *Journal of Economic Entomology* 55:964-970.

Appendix C

Potential Breakthroughs in Convenience Foods

Most people have never considered (or perhaps have abandoned) the idea of sorghum, millet, and the other African grains becoming prestigious foods for up-scale mass consumption. Everyone accepts that wheat is sold as bread, pastries, and baked goods; rice comes in all sorts of precooked forms; and maize is routinely available in convenient flour or grits. However, almost no one thinks of sorghum and millets in the same light. These African cereals are relegated to the limbo of foods suited only for personal use in rural regions by individual families who have to prepare their own food from raw grain.

But possible ways to upgrade Africa's own grains are on the horizon, and these deserve thorough investigation and development. Such processing breakthroughs can break the malicious mind-set, diversify the uses, improve the nutritive value, and boost the acceptability among consumers. Their success will create convenient-to-use foods, open vast new markets for Africa's farmers, and improve both rural economies and the balance of payments of many nations. In this particular sense, food technologists hold the key to the future of the lost grains of Africa.

This topic is far too broad to be covered adequately here. (It actually deserves a major international research endeavor.) Nonetheless, a few possible innovations—encountered while compiling this report—are mentioned below, just to provide perspective on some opportunities that are now languishing through lack of initiative.

POPPING

Popping is a simple technique that produces light, attractive, ready-to-eat products. It improves taste and flavor and it yields a crunchy, convenient food. Most people think of it as a process only for maize, and no wonder: popcorn is wildly popular among Americans and

others who know it well. What has hardly been appreciated, however, is that most of Africa's grains also pop. While less spectacular than popcorn, they do expand dramatically and they, too, take on an agreeable toasty flavor. In the future, popped forms of sorghum, pearl millet, finger millet, fonio, and perhaps other grains could find extensive usage.

As has been mentioned previously (pages 43 and 177), people in India already pop sorghum and finger millet on a large, and sometimes commercial, scale. They often mix together milk, brown sugar (*jaggery*), and popped finger millet to create a very pleasant dessert. Popped finger millet is also used in brewing.

For finger millet, as well as for Africa's other cereals, popping seems to offer many benefits. It is a promising way to increase the grain size, create ready-to-eat foods, and add flavor to what are often bland dishes. Something similar is happening in the United States with amaranth. This former staple of the Aztecs and Incas is making a comeback, largely as a popped snack food. Recently, a continuous popper designed to handle amaranth's extremely small seeds was patented.[1] Such a device may well be the key to commercially popping Africa's small-grain cereals as well.

Once the popped grains are available, many new foods are likely to be created. Indian food scientists have blended popped finger millet with legumes such as puffed chick pea or toasted green gram to form nutritious and very tasty new foods.[2] In Africa, something similar might be done using legumes such as peanut, cowpea, or bambara groundnut.

PUFFING

The process of puffing, a variant on popping, was discovered almost a century ago. Since then, cereals made from puffed rice and puffed wheat have been breakfast staples worldwide. Puffed oats and maize are now also produced.

In the puffing process the grain is placed in a sealed chamber and heated until the pressure rises. Then the chamber, or puffing "gun," is suddenly opened. Relieved of the pressure, the water vapor expands, blowing up the grains to many times their original size (for wheat, 8-16 times; for rice, 6-8 times). Finally, they are toasted and dried until crisp.

Puffing has probably never been attempted with African rice, fonio, tef, or the other African grains, but it is another possible way to

[1] The machine was developed by Edward S. Hubbard, American Amaranth, Inc., Bricelyn, Minnesota.
[2] Information from H.S.R. Desikachar.

boost the size of these small grains, add flavor, and produce quality convenience foods with high consumer demand.

MALTING

Germination also upgrades the quality and taste of cereals. The sprouting process, known as malting, releases amylase enzymes that break starches down into more digestible forms including sugars. The result is to liquefy, sweeten, and raise the nutritional value.

Malting is particularly good for children because they can better assimilate the partially digested nutrients.[3] During World War II, government authorities in Great Britain (to mention just one country) seized on malting as a way to prevent childhood malnutrition brought on by wartime food shortages. Malt extract was produced in large amounts and distributed for daily use by children. This thick, dark, pasty material may have looked awful, but children loved its sweet and pleasant taste. It is in fact still sold in parts of the world, not so much as a nutritional supplement but as an everyday food that people buy for its flavor. It is also the key flavoring ingredient in famous foods such as malted milk and Ovaltine®.

Why malting is not more widely used in these days of mass malnutrition is a puzzlement. Perhaps the process is so associated with barley that the two have become almost synonymous, and, because barley will not grow where malnutrition mostly occurs, it is never considered. What has been overlooked, however, is that finger millet and some sorghums are almost as good at malting as barley. Their amylase activity is also high. And they w*ill* grow where the malnutrition is rife.

It is perhaps the ultimate irony that malting is practiced every day in many African homes, but the fact that malted grains make fine foods is overlooked.[4] Finger millet malt, for example, is great tasting, easily digested, rich in both calcium and sulfur-containing amino acids, and an ideal base for foods for everyone, from the very young to the very old.[5] But most of what is made these days is used in fermentations that produce beer (see box, page 168).

[3] For more on this topic, see Appendix D. where the use of malts in preparing weaning foods is discussed.

[4] Villagers are not the only ones who misunderstand malting. Missionaries in more than one country have preached against it in the mistaken belief that malted foods are alcoholic.

[5] Malleshi and Desikachar, 1986a.

FERMENTING

Lactic acid fermentations are used worldwide to produce foods such as sour cream, yogurt, sauerkraut, kimchee, soy sauce, and pickled vegetables of all kinds. Except for making sourdough bread, it is so far not used widely to "sour" cereal products. But in Africa it is traditionally used to flavor and preserve porridges and to produce popular foods such as *bogobe* (sour sorghum porridge) in Botswana, *nasha* (sour sorghum and millet porridge) in the Sudan, and *obusera* (sour millet porridge) in Uganda. People in many parts of the continent prefer the sharp flavor of these fermented porridges.[6]

Despite its almost complete neglect by cereal science, acid fermentation is yet another process for upgrading a grain's taste and nutritive value. For the food supply of Africa, it is particularly promising. The lactic acid fermentation process is well known. It is generally inexpensive and requires little or no heating, making it fuel efficient. It yields highly acceptable and diversified flavors. And it usually improves nutritive value.

It is commonly used in households (at least throughout eastern and southern Africa) and remains one of the most practical ways to preserve food for hundreds of millions of hungry people who cannot obtain or afford canned or frozen foods.

Lactic acid fermentations make foods resistant to spoilage, thereby performing an essential role in preserving wholesomeness. The bacteria rapidly acidify the food to a pH so low that dangerous organisms are no longer able to grow. They also produce hydrogen peroxide, which kills organisms that cause food spoilage (the lactobacilli themselves are relatively resistant to hydrogen peroxide). Certain lactic bacteria (notably, *Streptococcus lactis*) produce the antibiotic nisin, active against gram-positive organisms. Others produce carbon dioxide, which also helps preserve foods, notably by displacing oxygen (if the substrate is properly protected).

The course of the fermentation can be controlled by adding salt. Salting limits the amount of pectinolytic and proteolytic hydrolysis that occurs, thereby controlling softening (as well as preventing putrefaction).

Although fermented porridges were once extremely popular in rural Africa and are still widely consumed, their popularity appears to be declining. Some consumers are turning to alien alternatives that are widely advertised, such as tea or carbonated drinks. In many districts, farmers (as we have noted earlier) are giving up sorghum and millet and are growing maize. And in others, people are said "to lack the will and the interest" to prepare traditional fermented porridges.

[6] The use of such fermentations to make baby food is discussed in Appendix D.

But for all that, fermentations have a future and deserve recognition and attention. For one thing, they are very promising for creating weaning foods that may overcome mass malnutrition (see next appendix). For another, lactic acid fermentations are promising as commercial methods of processing and preserving food as well as for creating business enterprises.

PRECOOKING

To help meet the demands of an ever hungrier Africa (not to mention the world), the partial cooking of grains looks particularly promising. When dropped into boiling water, most (perhaps all) of the grains described in the earlier chapters soften within 5 or 10 minutes. The hot water partially gelatinizes the starch so that the dough sticks together and can be rolled into sheets or squeezed into noodles.

Some food technologists have already begun applying such processes to sorghum and pearl millet.[7] In the future, precooking might be applied to most of Africa's native cereals to produce top-quality, ready-to-cook foods that are stable, more nutritious, and easy to store.

Below we highlight three techniques—parboiling, flaking, and extruding.

Parboiling8

Parboiling is basically the process of partially cooking grain while it is still in the husk (that is, before any milling). The raw grain is briefly boiled or steamed. (Generally, it is merely soaked in water, drained, and then heated.) Only after the resulting product is dried is it dehusked and decorticated.

What results is very different from the normal milled grain. Sorghum kernels, for instance, come out looking like rice: light-colored, translucent, firm, and intact—attractive in both appearance and aroma and much less sticky than normal. Of course, they still must be cooked to become edible.

Parboiling not only gelatinizes the starch in the grains, it also does the following:

- Makes the milling process more efficient. (In a recent trial

[7] In this regard, notable work is being done at the Central Food Technological Research Institute (CFTRI), Mysore, Karnataka 570 013, India. There. N.G. Malleshi and his colleagues, although thousands of kilometers from Africa, have been doing work of great possible significance to the future of African grains.

[8] This section is based largely on the paper by R. Young, M. Haidara, L.W. Rooney, and R.D. Waniska. 1990. Parboiled sorghum: development of a novel decorticated product. *Journal of Cereal Science* 11:277-289.

with soft-kernel sorghum, parboiling more than doubled the yield of decorticated grain.)

- Inactivates enzymes and thereby greatly extends shelf life. (It even improves the storability of pearl-millet flour, a material notorious for turning smelly during storage.)
- Kills insects and their eggs so that it reduces storage losses.
- Improves the grain's cooking characteristics. (Boiling parboiled sorghum, for instance, doesn't produce mush; instead, the kernels remain separate, whole, and very much like pilaf or rice.)
- Improves nutritional values. (This is notably because it helps retain water-soluble constituents—such as the B vitamins and certain minerals —that otherwise are thrown out with the cooking water.)
- Upgrades certain grains that have poor processing characteristics (the soft endosperm in finger millet, for example).

Given its now widespread use in the rice industry, parboiling is a surprisingly recent newcomer to commerce. Until the 1930s, it was hardly known outside South Asia where it was a village technology employed by poor people in their cottages. In the last 60 years, however, parboiled rice has rocketed into extensive worldwide use, and parboiling is now done on a giant commercial scale in countries such as the United States.

Parboiling is still good for village-level use, however. For example, field trials in Mali, using local sorghum and pearl millet, showed that it was practical, satisfactory, and boosted the yields from milling. Malian families tested the parboiled grains in local dishes and condiments (such as peanut sauce) and rated them very acceptable.[9]

At first sight, the extra energy and effort needed to parboil grains would seem to be a major disadvantage. However, the increases in yield and quality provide both the processor and consumer with substantial benefits.[10] Rice is already parboiled in the villages of some parts of Mali (not to mention half of India), which certainly suggests that the product is good enough so that people will find the fuel and put in the extra effort to prepare it.

Flaking

In this process, decorticated (pearled) grains are soaked, heated, partially dried (to about 18 percent moisture), pressed between rollers,

[9] These tests were run at Sotuba. The whole grain was washed, placed in cast-iron pots (covered) and heated in tap water over an open fire until the boiling point was reached. The pots were then taken from the fire and allowed to cool overnight. The next morning they were heated again and drained immediately after once more reaching the boil. The moist grain was next spread out in the shade to dry (24 hours for pearl millet and 48 hours for sorghum). The final product was decorticated with a mechanical mill.

[10] An increase of only 1-2 percent in the milled yield of commercially parboiled rice gives the processor enough profit to offset the extra energy costs.

THE POWER OF PROCESSED FOODS

Despite the reliance on sorghum and millet in some countries, and despite consumer preference for flour made from them, the industrial production and commercialization of local flour has barely been established in Africa. Sorghum and millet flours are still mainly produced by each individual household. On the other hand, the introduced grains—wheat, rice, and maize—are more commonly milled at commercial facilities.

This makes the foreign grains look superior and it holds back the local cereals. And the situation is worsening. Soon, the rural labor force could be insufficient. Thus, even if production is increased there won't be the people to process it. For example, in most regions it is the young women who process most of the grain, but increasingly they are going to school, getting jobs, or abandoning the countryside to seek opportunity in the cities.

In a sense, then, it is imperative to find and develop good profitable uses for millet, sorghum, and the others. And the time is ripe. With increasing urbanization and rising disposable incomes, the demand for preprocessed and convenience foods is accelerating. This is one reason why commercially milled wheat and maize flour are increasingly preferred. Sorghum and millet are much cheaper, but they are unprocessed and therefore less convenient to use. As a result, markets for locally grown sorghum and millet are diminishing, incentives for local production are deteriorating, and foreign exchange reserves are dwindling to meet ever-rising demands for preprocessed flours.*

In dry regions, processing facilities are particularly vital to the future of local cereal farming. There, sorghum and millet are essential for a viable agricultural community. Both crops are so drought tolerant they can grow where other cereals cannot. When imported flour crushes the demand for them, the farmers are left with no outlet for their grain in years of good rainfall when they have a surplus. And when market prices fall, farmers cannot afford the inputs, such as fertilizer, that can keep their yields up.

If, as has been noted, markets for local flour and processed foods are developed, a large and healthy trade between a country's own sorghum, millet, and fonio farmers and its cities could operate to everyone's benefit.

Success with processing would likely transform Africa's native cereals into big-time, high-value worldwide foods.

* FAO reports that between 1961 and 1977, imports of wheat, rice, and maize to Africa increased between 5 and 10 percent a year, whereas the production of sorghum and millet increased 0.2-1 percent.

and, finally, completely dried into flakes.[11] The resulting product is a convenience food of many potential uses. The flakes store well and hydrate quickly when dropped into warm water or milk. They can be used in many types of sweet or savory dishes. When deep fried, they burst into light and crispy products.

African grains are particularly suitable for flaking because they are small and soak up water quickly. But although the process is simple, it is seldom used today. The holdup seems to be purely technological: grain-flaking machines are large, expensive, and inappropriate for Third World use. Now, however, a simple, inexpensive machine capable of flaking cereals in villages has been developed in India.[12] A unit has been installed in a village near Bhopal, and the people took to it and were able to operate it without supervision.

This type of invention could open up a new world for sorghum, millet, fonio, and other grains. More than 30 years ago, South African researchers mixed sorghum flour with water, then passed the slurry through a hot roller that both cooked and dried it. The resulting ready-to-eat flour proved very palatable and would keep for at least 3 months without deteriorating. Whole milk or skim milk (used in place of the water) produced a similar flour that was not only tasty but rich in protein, calcium, and phosphorus. Processing costs were reportedly low.[13]

Extruding

Extruding is a variant of the flaking process. The moistened and half-cooked grains are squeezed out through small holes. It is how noodles and pastas of all kinds are prepared. It, too, improves water absorption and cooking quality. Noodlelike products can probably be made from all the grains highlighted in this report. The pearled grains are first soaked for a day or two, then drained, mashed, cooked, extruded, and dried.

Noodles prepared from blends of finger millet and legume flours are already being used in India to form nutritionally balanced foods that can be used as supplementary foods for malnourished children.[14] When deep fried, they make excellent crispy products—said to equal those

[11] This is pretty much the basic process worked out by J.H. Kellogg in his kitchen in 1906. What resulted was the famous Kellogg's Corn Flakes.

[12] At the Central Institute of Agricultural Engineering in Bhopal. The machine consists of a hopper, four "large" rollers (112 mm x 230 mm). a smaller roller (88 mm x 230 mm), and a gear train to provide the differential speed needed to squeeze out the flakes. The whole unit is powered by a 2 hp electric motor, and the power required is only 150 W. The rollers are hollow and made of nylon to reduce weight and noise. The flakes come out as thin as 0.35 mm.

[13] Coetzee and Perold, 1958.

[14] Kumate, 1983.

SUCCESS BREWING IN SOUTH AFRICA*

Mohale Mahanyele's story exemplifies the immense business opportunities to be found in commercializing the traditional foods made from African grains.

In the late 1980s South Africa's government set out to privatize the sorghum-beer industry. For at least 20 years, sales had been dropping, as workers migrated to the cities and left the rural villages where the low-alcohol, high-protein drink is embedded in the culture. The government hired a management consultant, Mohale Mahanyele, to advise it on how to get rid of the business. His task seemed like a thankless one; the sales decline seemed inexorable. One analyst said the authorities were merely unloading "an old Third World product doomed to die."

Mahanyele did not agree. "There were a lot of leaders in the African community who thought we were being set up to fail," he says. "But I thought differently. Here was a drink that had always been associated with our festive occasions, and it had been taken away from us and tainted. It was humiliating, degrading. I wanted to restore the dignity of sorghum."

Armed with that vision, Mahanyele himself set out to buy the business from the government-run monopoly in 1990. It seemed like a foolish notion. He had to raise $20 million to purchase the corporation and its 21 factories, but he had no access to white capital. So he did something never before attempted in his country: he sold shares to fellow Africans, building on the centuries-old custom of *stokvels*— small, informal savings societies—in traditional communities.

National Sorghum Breweries ended up with 10,000 shareholders, more than 90 percent of whom are black—a novel arrangement in a country where few blacks own the roof over their heads. But Mahanyale's problems were far from over. In addition to the dropping sales, he had to overcome sorghum beer's political stigma, created during the 80 years when the white-minority government ran the business. To his own people, "Kaffir beer," as it was known, had become a symbol of white oppression. But Mahanyele succeeded. Today, National Sorghum Breweries is by far South Africa's most successful black-owned business. It has nearly doubled its volume in the past three years, while

* This vignette is adapted from an article by Paul Taylor (*The Washington Post,* July 21, 1993).

paying annual dividends of 20 percent or better. "We understand the product," he says. "We have a color fit and a culture fit with our customers."

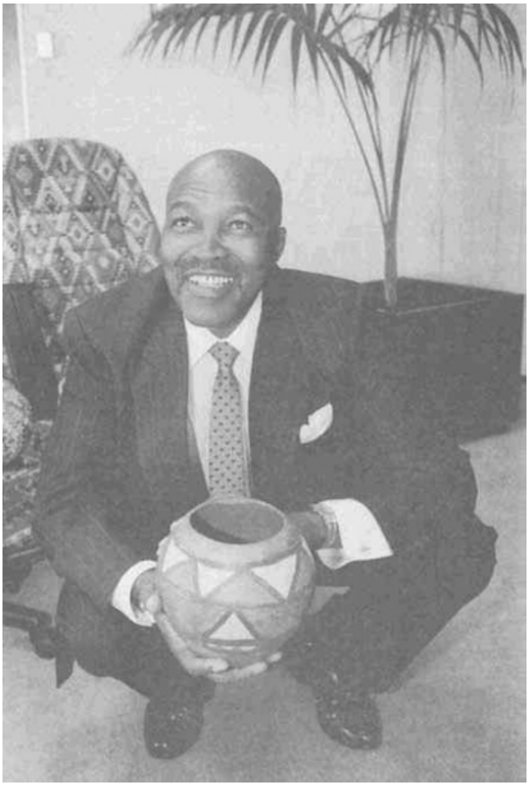
Through the development of the sorghum-brewing business, Mohale Mahanyele has become South Africa's foremost apostle of black economic empowerment. The company's board and management team, once all white, is now nearly all black. Most of its contractors are black, including 500,000 small businessmen who distribute the beer to stores throughout the country. It employs a quarter of South Africa's black accountants, and is putting more than 100 of its executives through an MBA program that it runs on the premises.

Today, National Sorghum Breweries is beginning to diversify into other products—food, soft drinks, computers and, most daunting of all, conventional beer, a market in which a giant white-owned brewery currently has a 98-percent share. Can more success be far behind?

Sorghum beer has a rather thick consistency with a refreshing acid flavor; the alcohol content is only 3-4 percent by volume, but large amounts are apt to be consumed on festive occasions. Women have brewed it in Africa's villages for centuries (see page 168).

No one has ever written a definitive work on African beers and their nutritional or social roles. This could be a major project for African scholars. These beers are more important than most people realize. A special quality is their safety. Because they are highly acidic (ranging between 3 and 4 on the pH level), they are free of bacterial contamination. So far, however, science has shied away from investigating such beers. Anthropologists and nutritionists refer to them, but that is about all. This is surprising because sorghum beers are an important part of life throughout most of Africa below the Sahara.

In his executive suite in a suburban office tower in Johannesburg, Mohale Mahanyele merrily lowers himself on his haunches onto the plush carpet. He is demonstrating the traditional way to consume sorghum beer. “You gather around circle, and everyone squats,” he says. “Then you pass around the calabash, and everyone takes drink. If you are standing up it's a sign of disrespect.” (Louise Gubb, courtesy *Washington Post*)



prepared from rice. Noodles from finger millet and other African grains could probably be economically produced in small-scale industries, as the equipment needed is not overly complicated and the capital investment is modest.

LEAVENING LOAVES

Raised bread has become what is perhaps the world's premier food. Wherever it is introduced people eagerly adopt it and clamor for more. Unfortunately, however, leavened breads can be made only from wheat or rye, neither of which grows well in the tropical zone where the neediest people are concentrated.[15]

For at least 30 years scientists worldwide have searched for ways to make raised bread without using wheat and rye. Such work could have profound implications for Africa (see box, page 310) but, despite the theoretical promise, nowhere has there been much practical success so far. Local staples tend to make unattractive, short-lasting, poor-rising breads that the public shuns. Dough strengtheners and other modifiers (such as emulsifiers, pentosans, xanthan gum, and wheat gluten) can be added. They make acceptable breads, but usually they must be imported and are expensive.

Now, however, there is a possibility of a breakthrough: research has shown that it is possible to prepare loose-structured bread from local grains using a swelling and binding agent. Different types have been tested. Dried pregelatinized cereal or tuber starches have shown some success. Glyceryl monostearate is said to be effective. Locust bean gum, egg white, and lard are also fairly good. These compounds act to bind the starch granules together, making it possible for the dough to hold carbon dioxide gas and thereby to rise. Baked products obtained this way have greater volume, softer crumb, and a more regular texture.

FAO Bread

Although none of the techniques has yet yielded light, high breads like those from wheat, there has been partial success. Perhaps the most advanced is a project operated by the Food and Agricultural Organization of the United Nations (FAO). The FAO method involves

[15] Gluten gives bread its light texture, and this elastic protein is unique to wheat and rye. When the dough is fermented, gluten's network of protein strands traps carbon dioxide released by the yeast. As the gas bubbles up, it raises the dough into the light. open texture of leavened bread. Triticale. a man-made hybrid between wheat and rye. not unexpectedly, can also produce raised breads. (Triticale is described in a companion report. *Triticale: A Promising Addition to the World's Cereal grains.* For a list of BOSTID publications, see page 377.)

boiling part of the flour from a local cereal (or root) until it thickens into a gel strong enough to hold the gas released during breadmaking. When added to local flour, yeast, sugar, and salt, this starchy substitute for gluten produces a puffy bread of acceptable texture, taste, and color.

AVOIDING THE WHEAT TRAP

Researchers in several southern African nations have banded together to produce a white sorghum that can be locally grown to make flour for bread and mealies (cornmeal). They seem to be already on the verge of success. If so, they will have developed the first truly African bread grain. The following is a recent announcement from PANOS, an international organization that specializes in disseminating Third World news.

Fifty scientists from Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, Swaziland, Tanzania, Zambia, and Zimbabwe, the 10 countries grouped in the Southern African Development Coordination Conference (SADCC), are now being trained to breed and produce sorghum hybrids. Soon, that number of trainees is expected to double. Why all the excitement?

To help reduce the region's dependence on imported wheat, researchers in Zimbabwe have developed hybrid strains of sorghum and millet that are designed for use in making flour and bread. The work at the Matopos Research Station near Bulawayo forms part of a drive to reduce food shortages in the SADCC countries.

For most people in the region maize is the staple, but the crop does not grow well in the drier areas. Researchers are trying to develop substitutes that can be grown there and mixed with wheat for bread or maize for mealies. Any surplus could be sold to make high-quality malt.

In farm tests, the new hybrids have produced bigger yields than existing varieties. The researchers expect to have white-grained hybrid sorghum for milling very soon. It is hoped that the white sorghum will satisfy a popular preference for white maize meal. A local milling company is already working with a nongovernmental organization called Enda-Zimbabwe to set up pilot mills in rural areas to grind the hybrid grains for bread.

Before people in areas of low rainfall can be persuaded to abandon their often futile efforts to grow maize, good varieties of the new hybrids must be available in large quantities of the seed.

Reportedly, this new technology is simple, inexpensive, and uses nothing but local ingredients. It can, for example, produce leavened loaves using sorghum, millets, and other African grains.

Leavening with Fungus

Recently, food scientists in India have found that fermenting a mixture of grain and pulse (legume seed) can produce a gum thick enough to act like gluten. This special process, locally known as *idli* or *dosai* fermentation, involves the microorganisms *Leuonostoc mesenteroides,* which is used in other parts of the world for producing dextran gums from sucrose. Using this fermentation, a mixture of rice and *dahl* (made with black gram or other legume) can be turned into a dough that will produce breadlike products without employing any gluten. Either the legume, the microorganisms, or the combination produces a gum that holds the carbon dioxide gas, thereby leavening the products. It is a fermentation that enables raised breads to be

THE WHEAT TRAP

Africa is finding itself more and more caught up in what is being termed the "wheat trap." During the past 20 or 30 years, certain governments as well as private companies have responded to consumer demand by establishing wheat mills. As a result, various countries now spend large amounts of foreign exchange importing wheat to feed those mills. The bulk of the flour produced is used to make bread for the working population, as well as for the small expatriate population living in the towns and cities.

Bread is a convenient food because it is ready to eat, easily carried around, and not messy like porridges and gruels. Its taste is highly acceptable, it gives a feeling of bulk and fullness, and it is relatively cheap. With large numbers of people migrating from rural areas to the cities, the demand for bread has increased.

However, the population is being fed on food the country does not grow, with scarce foreign exchange being used to import wheat to produce flour. More foreign exchange is also spent on spare parts and foreign managers to maintain and run the flour mills. The process not only damages the economy but the indigenous African cereals as well. They are being left in a state of underdevelopment and inadequate processing.

J. Maud Kordylas

made without any wheat or rye.[16] Perhaps other fermentations or other substrates for this fermentation to do this job can also be found.

Biotechnology

With all the advances in biotechnology these days, it seems likely that the genes that cause gluten to form in wheat will soon be isolated. Inserting them into the chromosomes of Africa's native grains could bring profound changes. Suddenly, sorghum or pearl millet would (at least in theory) produce bread that rises without any extra help. This is not a far-fetched idea. Indeed, it will be surprising if it does not come about within the next decade or two.

[16] Information from N.G. Malleshi and H.S.R. Desikachar.

Appendix D

Potential Breakthroughs in Child Nutrition

As in the three previous appendixes, we report here innovations relating only indirectly to Africa's cereals. Once again, these seem of notable significance to the continent as well as to the future of the traditional grains. In this case, the potential breakthroughs are of great humanitarian significance—no less than a means by which Africa may at last put behind it the horrors and heartbreak of childhood malnutrition.[1]

WEANING FOODS

In most parts of the world, baby foods are commonplace. In North America, for example, supermarkets may carry whole aisles of liquefied and semisolid concoctions carefully created from cereals, vegetables, and fruits. Through these foods, a child gets a diet that is easily digested, rich in energy, and balanced in protein, vitamins, and minerals. Such foods help the child make the complex and otherwise life-threatening transition from mother's milk to adult fare.

The tragedy for Africa's millions of malnourished children is that comparable bridging foods are unavailable to, or at least far beyond, a family's financial reach. A child in Africa, therefore, faces a cataclysmic change from a balanced and hygienic liquid diet of mother's milk to an unbalanced solid adult food that is often very unwholesome. Although the young milk-fed bodies are basically unprepared for such

[1] As before, the coverage is far from exhaustive. In fact it is based on a single report. This report, a quite technical 400-page document full of data and diagrams, includes information contributed by several dozen nutritionists and food technologists from all parts of Africa. In this appendix we can only skim some highlights. The details can be found in the full report: D. Alnwick, S. Moses, and O.G. Schmidt, eds. 1988. *Improving Young Child Feeding in Eastern and Southern Africa: Household-Level Food Technology*. Report No. IDRC-265e. International Development Research Centre, Ottawa, Canada.

a switch, they must start digesting foods of alien consistency and inferior quality. Moreover, they often must do this while battling new and numerous intestinal infections introduced through unclean hands and utensils as well as through inadequate cooking.

This situation constitutes the gravest emergency facing children today. As UNICEF's executive director, James P. Grant, has pointed out: "The period of weaning, during which a young child becomes accustomed to the change from a diet consisting solely of his or her mother's milk, to one totally devoid of it, may take a year or more, and in much of the world this is perhaps the most dangerous period of the child's life. Many will not survive it. Of those that do, too many will be stunted in body, and perhaps in mind, and never be able to attain the full promise of their birth."

Today this hazard falls heaviest on Africa's children. Perhaps in the future centrally processed weaning foods will, as in North America, serve the children's needs. However, at present the cost of such products and the inability to distribute them throughout the rural regions makes this impractical. The only answer for the moment, then, is weaning foods that can be prepared either in the home itself or at least in nearby locations in the rural districts.

Given the extent of present malnutrition, one could be forgiven for concluding that household weaning foods are an impossibility for rural Africa—that appropriate ingredients must be unavailable, or that the people cannot make foods appropriate for children. But a number of knowledgeable nutritionists and food technologists believe that bridging foods for the critical nutritional years of each new generation can indeed be produced locally and cheaply. And, in their view, it is the traditional native grains—sorghum and finger millet, in particular—that are the key to this vital and life-saving possibility.

The reason for this is unexpected but understandable.

Those who, in the past, blamed malnutrition exclusively on the lack of certain nutrients in the foods were largely wrong. The local cereal products are not as poor in nutrient quality as was (and is) generally claimed. Today's nutritionists increasingly blame the low quantity of solids (what they call the "nutrient density") in the foods used for feeding the very young.

Africa's traditional weaning foods are watery gruels based on boiled cereal. These may have the right consistency for a child whose sole diet has been milk, but they are just too dilute. A gruel whose consistency is acceptable to a one-year-old contains merely one-third the food energy of a typical Western weaning diet. A child simply cannot consume enough to meet its energy and other nutrient requirements. Even when stuffed with gruel to its limit, a small stomach contains too little solid to keep its owner fed for very long. And most

of the children must get by on only two feedings a day because mothers who work in the fields have no time to boil batches of gruel throughout the day. The children therefore get fed only in the morning and evening when the rest of the family's food is prepared.

A tragic irony is thus becoming apparent. Although the gruels are too thin, the porridges the mothers are cooking for the rest of the family would be satisfactory except for one fact: they are too thick to be swallowed by an infant. A stiff porridge is useless to anyone who cannot eat solids.

What can be done? The answer, the nutritionists now say, is to take a small part of the adults' thick porridge and change its consistency so any child can "drink" it. How? By the age-old African methods of malting or fermenting (see Appendix C). Both procedures break up boiled starch so that it collapses into smaller saccharides, including sugars, and releases the water that keeps it thick.

For the rest of the world, malting and fermenting are not everyday household operations, but in Africa they are. Indeed, these two processes are probably better known at the household level in Africa than anywhere else in the world. Both techniques require only a minimum of equipment and appear to be good ways to turn stiff starchy porridges into liquid weaning foods.[2]

MALTED FOODS

Given what is currently available in an African village, probably nothing can compare with malting as a means for carrying rural babies across the nutritional abyss between mother's milk and adult foods. The previous appendix discussed malted grains and the potential they offer in and of themselves. Here, however, we discuss another side of these versatile materials: their use as culinary catalysts for modifying starchy foodstuffs. This is a process all but unknown to most people, but it is by far the biggest use of malted grains and is conducted all over the world. It is, in short, the vital first step in making beer and whisky.

Perhaps because of this association, malting has been saddled with a somewhat seedy reputation. But it is a simple, safe process that produces no alcohol and should be more widely used and better known to cooks everywhere.

In Africa, malting has a special promise. Two of the native staples—finger millet and certain sorghums—are rich in the malting enzymes (amylases) that break down complex starches. To liquefy even the

[2] Although germination of cereals is mainly associated with the preparation of local beers, there are a few examples of this procedure being used to prepare local weaning foods with low dietary bulk.

thickest cereal porridges takes only a small quantity of flour from germinated sorghum or finger millet. When this flour and the porridge are heated slowly, the amylase enzymes hydrolyze the gel-like starch in the porridge so that it collapses and can no longer hold water. In this way, sprouted sorghum and finger millet can turn a pasty porridge semiliquid in minutes.

Moreover, the food not only thins down, it becomes, to a certain extent, predigested so that it is easier for the body to absorb. In addition, the enzymes hydrolyze not only the starches but some of the proteins as well. They also reduce antinutritional and flatus-producing factors, improve the availability of minerals, and enhance some of the food's vitamin content. Further, the malting process imparts sweetness and flavor that makes for a tasty end product.

Considering the extent of malnutrition, it is more than ironic that individuals throughout Africa know more about this process than people anywhere else in the world. Indeed, throughout sub-Saharan Africa, millions of homes have a crock in the corner that contains malted grain. A small sample of the contents would transform thick porridges into baby foods sufficiently liquid for children to consume and sufficiently nutrient-dense to keep them healthy. Tests have shown that adding a little germinated cereal while a porridge is being prepared doubles the amount of food energy and nutrients a child can ingest. However, at present the malt is used only to make beer, almost never to prepare weaning foods.

Experiences in Tanzania suggest that the concept of liquefying porridges for baby food is not an impractical dream. In the early 1980s, scientists at the Tanzania Food and Nutrition Centre found that small quantities of flour from germinated sorghum or finger millet could be used to thin the traditional viscous porridges.[3] They called their product "Power Flour." When a spoonful was added during cooking, porridges thick enough to hold up a spoon turned liquid within 10 minutes.

The researchers found that mothers in Tanzania's villages were only too willing to use Power Flour. Most of the mothers knew how to prepare germinated cereals for brewing but knew nothing about making foods for their children from them. However, because the procedure was already so well known, they quickly adopted it.[4]

Although it is ironic (even tragic) that malting is so well known across Africa, it is also an advantage. Using germinated cereal to improve weaning foods is simply a variation on an already widespread

[3] Mosha and Svanberg, 1983.

[4] In fact, it is hard to avoid the conclusion that Power Flour (or some barley-based counterpart) could find a place in kitchens worldwide, including the most sophisticated. With an aging world population and in some wealthy countries an intense interest in dieting, liquid diets and highly digestible foods of all kinds are now much in vogue and are the bases of billion-dollar industries.

technology—not a strange foreign food or technique to be imposed by an outside authority. Local, national, and international efforts to stimulate appreciation of this could see a new level of weaning foods sweep across Africa with little outside involvement. The key in many areas may be to educate village brewmasters to the potential of a second product from their ongoing malting operations.

Sorghum is the most widely available malting grain in Africa, and it has been used in most of the nutritional experiments so far. However, finger millet is a better choice: it has a higher amylase activity; it has no tannins; it develops no potentially toxic materials on germination;[5] it is rich in calcium and methionine, both of which are needed for child growth; its malt has a pleasant aroma and taste; and, finally, it does not mold or deteriorate during germination.

Considering the fact that the technology and raw materials are common in most village situations, why has this immensely beneficial practice not been more widely used? For one thing, the process of germinating grain does take some time; mothers, already weighed down with burdensome work loads, tend to reject anything that takes up more of their day. However, germinated flour need not be produced daily. Indeed, small portions can be set aside whenever a fresh batch of beer is begun. In addition, as in the case of Tanzania's Power Flour, the malt could be made centrally and sold widely. Unlike the weaning foods themselves, it is a stable, concentrated material that is used only a pinch at a time.

FERMENTED FOODS

The fermentation of cereals by lactic-acid-producing bacteria has been discussed in the previous appendix. It, too, appears to be a way to prepare weaning foods. Like malting, fermentation is a household-level food technology that reduces the viscosity of stiff porridges (although not as much and not in minutes). It raises the levels and bioavailability of proteins, vitamins, and minerals. It enriches the foods through the synthesis of some B vitamins, and it adds flavor. On top of all that, it helps protect the foods from diarrhea-causing microorganisms.

As has been noted in Appendix C, lactic fermentation is practiced throughout the world to make pickles, sauerkraut, soy sauce, sourdough bread, and other popular foods, but it is especially well known in Africa. From Senegal to South Africa "sour" porridges are popular.

[5] Certain sorghums on sprouting show a marked increase in hydrocyanic acid. This is worrisome, especially when the product is to be fed to a very small child. However, it seems probable that the normal cooking of porridges quickly drives off the cyanide.

However, although still widely consumed, they are often overlooked as weaning foods.

But sour porridges seem to fulfill many of the characteristics required, and they also reduce the risk of pathogenic diarrhea—Africa's leading cause of infant death. They save time and energy as well, and might be very suitable for use during the day when a working mother has no time to cook.

A few fermented foods are already employed as weaning preparations. One example is *ogi,* a blancmange-like product that is one of Nigeria's most important foods. *Ogi* is created by fermenting a slurry of sorghum, millet, or maize. Adults eat it for breakfast, but some is kept aside and used as a weaning food.

There are possibilities, too, of combining fermentation and malting. Thus, fermented doughs, such as *ogi* or *ugi* (a similar product widely eaten in East Africa), might be liquefied with Power Flour into forms that weanlings can "drink." In that way children could ingest more, and the double processing would likely produce highly digestible foods, easy for any young, old, or sick bodies to assimilate.

Appendix E

After Words

While compiling this book, we were in contact with several hundred researchers who specialize in the various crops described. Along with their technical advice, some sent in provocative quotes, valuable for their pith and perceptiveness. In addition, during the four years that have gone into this book, we came across a number of equally intriguing quotes in the published literature. All in all, there were too many to include in the body of the text, so a selection of them is appended here. Some contradict each other, a reflection of the contributors' different visions and of the complexity of the issues. Each, however, contains insights that complement the earlier parts this book, which perforce had to be focused exclusively on the plants and their promise.

Philosophical Overview

The negative trends in Africa are not solely due to lack of knowledge. We shall claim too much if we say "give us money, we will do research, and we will solve the African food problem."

A.H. Bunting

The resources of farmers are not confined, let us remind ourselves, to the classical factors of land, labor and capital, although by suitable definitions we can fit all resources into one or other of those omnibus packages. We have to think also of seed, equipment, knowledge, chemicals, credit and many other things, as well as of external encouragement, services and support, particularly from the policy of governments. Development in Africa might well take a different course if governments were able to be more effective. Many African governments and government services are inexperienced and some are unstable. Many of them have great difficulty in forming and executing development plans.

A.H. Bunting

Farmers are rightly suspicious of the counsel of anyone who does not himself have to live by the results.

John Kenneth Galbraith

African farmers are not a bunch of village idiots; far from it. They can squeeze more out of a hectare than you or I could, and under difficult circumstances.

Jack Harlan

At least eleven hundred million people do not have enough to eat. Many of them live in countries that cannot afford to import food and where per capita domestic food production has declined since 1980. Most of these countries are in Africa, where the gap between food production and demand is expected to quadruple by the year 2000.

Inji Islam

What Africa needs is more agricultural research conducted by well-trained scientists with good support. It should include—at the least—plant breeding, pathology, agronomy, biotechnology, entomology, and soil science.

Arthur Klatt

The right technology—be it genetic or agronomic—will be put to use. If it increases yields economically, Africa's farmers will adopt it.

Arthur Klatt

Unless we satisfy the basic needs of four billion poor, life for the rest of use will be extremely risky and uncomfortable. Struggling farmers . .. threaten environmental stability, while the growing masses of urban poor are a menace to political stability.

Klaus Lampe

These "old" plants are neglected mostly because both local and foreign "experts" are prejudiced against them, but also because of the experts' own preference for anything that is new!

James M. Lock

The promotion of any indigenous crop must be done within local constraints of labor availability, gender relations, cultural constructs, and environmental stress. If local constraints, practices, and beliefs are not realized, promotion of the crop will not succeed.

Clare Madge

Of the two billion persons living in our developing member countries, nearly two-thirds, or some 1.3 billion, are members of farm families, and of these are some 900 million whose annual incomes average less that $100 . . . for hundreds of millions of these subsistence farmers life is neither satisfying nor decent. Hunger and malnutrition menace their families. Illiteracy forecloses their futures. Disease and death visit their villages too often, stay too long and return too soon.

The miracle of the Green Revolution may have arrived, but, for the most part, the poor farmer has not been able to participate in it. He cannot afford to pay for the irrigation, the pesticide, the fertilizer, or perhaps for the land itself, on which his title may be vulnerable and his tenancy uncertain.

Robert McNamara

President, World Bank [1973]

The persistence of child malnutrition in Rwanda is attributed largely to a lack of time and money on the part of the mothers. In the northern parts of the country, women spend nearly 10 hours in the field and so can prepare the family food only once or twice each day; this food is usually high in bulk but low in nutritional value and is, therefore, inadequate for feeding young children.

M. Ramakavelo

One of the problems that makes the task of the prevention of famines and hunger particularly difficult is the general sense of pessimism and defeatism that characterizes so much of the discussion on poverty and hunger in the modern world. While pictures of misery and starvation arouse sympathy and pity across the world, it is often taken for granted that nothing much can be done to remedy these desperate situations, at least in the short run.

There is, in fact, little factual basis for such pessimism and no grounds at all for assuming the immutability of hunger and deprivation. Yet those unreasoned feelings dominate a good deal of public reaction to misery in the world today. In fact, pessimism is not new in this field, and has had a major role over the centuries in dampening hearts and in forestalling preventive public action.

Amartya Sen

Instead of running away from these traditional products, we should be encouraging their use as quality foods that are as good or maybe even better than some of the foods people are presently substituting for them.

S. Vogel and M. Graham

Cereals in General

There is no doubt that cereals selected and cultivated by man are the basis for a stationary human culture as in the cities and villages of the world. The apparent value of the cereals was high convenience in storage and in cooking quality as well as a pleasant smell and bland taste of the final product combined with a high level of satiety after consumption.

Lars Munck

One of the possible reasons of the lack of research on native grains is that many African postgraduates go abroad either to USA or Europe and do their higher university degrees on wheat or maize. When they return, it is quite natural for them to continue their studies. (I have seen this happening in the past here in Australia but this is now changing.) It would be a step in the right direction if these postgraduates work on the crops of their own country for these degrees. (As a bonus it might even broaden the thinking of their supervisors.)

Donald F. Beech

There is no doubt that the human body was designed mainly to get calories from carbohydrates—starches and sugars—and since most starchy foods are fairly bulky it can be actually quite difficult for children to consume enough carbohydrates in a day if they come entirely from starchy foods like bread and potatoes and root vegetables.

John Birkbeck

Some 80-85 percent of the population in many African countries subsists on farming, and this large segment needs to be helped in improving itself. As improvements occur in agriculture and as it becomes less marginal and less subsistence-oriented, opportunities will need to be created for people to move to other sectors of activity.

Norman E. Borlaug

Although starchy fruits, roots, and tubers will continue to be important in the diets of African people in many countries and regions, much of the extra food needed will consist of cereals.

A.H. Bunting

There are many weaknesses in the output delivery systems such as physical infrastructure, transport, markets, storage, processing, wholesaling and retailing, and prices. These components determine the extent to which farmers can sell off the farm, which is the essential nexus in the whole business of agricultural and rural development.

A.H. Bunting

These cereal grains supply man with 60 percent of his energy and 50 percent of his daily protein requirements . . . the volume of grain required each year to satisfy man's needs can be calculated to be a highway of grain 2 meters high by 23.5 meters wide, that circles the earth at the equator. Approximately 1000 meters of new highway must be added each year to satisfy population increases.

Vernon D. Burrows

In Africa in the 1970s, the total area under all three cereals [sorghum, maize, and millet] increased by 8 percent, while mean yield declined by 1.5 percent and the human population increased by 29 percent. Unless this trend can be reversed, there is real trouble ahead.

Hugh Doggett

Often, a new variety fails to enter the traditional agricultural setup because no one checked if it will make the preferred foods at an acceptable quality. In Ethiopia, for example, bread-wheat varieties have been identified, but the farmers only grow them for cash as they cannot make good bread or grits using the traditional food-making techniques.

Sue Edwards

An essential feature of African diet is that the staple food—either maize, sorghum, millet, rice, cassava or wheaten bread—supplies about 80 percent of the people's calories, compared with approximately 30 percent eaten by Europeans in the form of bread. For Africans, the staple food is not merely the main source of carbohydrates, but also of proteins, minerals and vitamins.

M. Gelfand

Politics is probably the biggest "stumbling block" in Africa. In one country, they told me that the farmer could double the grain yield of pearl millet with existing agronomic practices but when the farmer did this, the government cut the price in half.

Wayne W. Hanna

The colonial literature is full of nonsense about "scarcity foods." They [the colonials] thought people harvested wild grass seeds because they were hungry and did not know that these were staples and gourmet foods.

Jack Harlan

A major widespread constraint to increased production that remains in Africa, in contrast to Southeast Asia, is that of unstable grain

markets. In consequence, rural families grow sorghum and pearl millet by the most reliable methods to meet their own needs and produce relatively little surplus to market. When there is a good year, everyone has a surplus and the market price falls catastrophically. Very rationally, farmers invest their efforts into cash crops or some other enterprise where returns are more assured.

R.C. Hoseney, D.J. Andrews, Helen Clark

Since the most ancient of days, the destiny of humanity has been inseparable from grain. Even today in the age of the microchip processor, humanity's affairs remain closely linked to the Fates attending cereal grains.

KUSA

African cereal production has two great weaknesses: there are no facilities for producing top-quality seed and there are no conduits for conditioning, storing and distributing it. Africa is full of entrepreneurs and there is a tremendous opportunity for them to start businesses selling quality seed. India started its own seed-trade that way: entrepreneurs began selling locally produced elite seed to their neighbors. Gradually, an entire distribution system developed.

A. Bruce Maunder

Nowhere in Africa are grains traditionally grown for "yield per hectare." Rather, they are grown for basic ingredients of specific foods such as ugali, injera, couscous, or beer.

J.F. Scheuring and M. Haidara

I suggest that researchers are now avoiding many of these traditional cereals because they consider it *infra dig* to use simple breeding and selection technology. The crops' status suffers from solely because there are no high-tech (genetic engineering, etc.) papers in the literature.

Gerald E. Wickens

In cereal production, Africa's greatest weakness is that there is little local storage. At harvest time farmers must sell their grain, regardless of price. Even in the United States, the drop in grain prices can be startling at harvest time, but most American farmers have their own storage and any farmer can rent storage, either locally or near the markets (which may be thousands of miles away). This allows the farmers the chance to wait and benefit from price rises after the harvest. It also buffers price swings, which benefits everybody except the speculators.

In Africa, the situation will change when a large demand for sorghum and millet flour develops. That will create a need for year-round supplies, and storage capacity will have to be created to provide millers with grain during the off-season. This will serve to draw off grain stocks during flush seasons while maintaining grain stocks during periods of shortage. In turn, it will allow farmers to hold their grain until they're happy with the price. It will also give the farmers an incentive to use superior seedstock, especially because prices won't fall as much during good years.

John Yohe

Plant Breeding

New variety types have to complement a farmer's food security strategy. Farmers in southern Mali have related to me that pearl millet and maize have expected storage times of three years, sorghum up to seven years, and fonio of well over seven years.

D.J. Andrews

I am sure that breeding for multiple objectives is essential if we are to attain our objectives sufficiently rapidly to benefit hundreds of millions of farmers and consumers by the year 2000.

S.C. Harland transformed Tanguis, the main cotton of Peru, by what he named the mass pedigree system of selection. By setting standards for six characters which could be measured on single plants, rejecting plants or small bulks in which these characters were below the norm or the arithmetic mean, and by advancing the standards in successive years, he soon produced populations of improved quality which yielded very much more than before. Starting from preliminary observations in 1940, the first wave of about 500,000 kg of improved seed was issued in 1943; and by 1949 yields around I ton of lint per hectare were being harvested on a field scale by some farmers. In respect of characters other than those for which they had been selected, the new populations were genetically heterogeneous and further improvement in them was evidently feasible.

A.H. Bunting

There are still abundant examples of major plant breeding programs which do not take account of the real constraints faced by many farmers. This is equally applicable to national and to international programs. The importance of this is vividly highlighted by the fact that after forty years of breeding on sorghum and millet at internationally supported research stations in West Africa, less than five percent of

the crop is planted to such material. The products simply do not meet most farmers' needs.

Stephen Carr

There has been a tendency to so under-rate the value of traditional cultivars that the extension staff ignore them. In so doing they miss the opportunity to provide a well-worthwhile service to their clients.

Stephen Carr

The germplasm story requires a whiff of skepticism. While the collections may not have *everything* (do they ever?), the real problem is to use what we have. We need more *real breeders* and fewer people pontificating about germplasm.

Geoffrey P. Chapman

Time has come when our breeding strategy has to change from the one where land is tailored to suit the requirements of a high-yielding cultivar, to where we tailor the cultivars to suit the harsh and ordinarily inhospitable habitats where the small farmers have to grow their crops.

T.N. Khoshoo

Above all, it is the imagination and ingenuity of the breeder that will be the decisive element in producing any new cereal crop in the future.

C.N. Law

Much progress has been made in the training of African scientists, such as by the Title 12, Sorghum-Millet Collaborative Support Research Program, INTSORMIL. Whereas vehicles and computers have been supplied to their in-country projects, little or no input has been given to adequate seed storage. Therefore, the maintenance of lands races, varieties, and breeding lines requires frequent re-increases; inefficient activity with risks of losing the original genetic composition.

A. Bruce Maunder

Simple harvesting and processing machines could greatly increase the effectiveness of seed production, and at minimal cost. Even on research stations in Africa, it is common to see sorghum and millet being pounded with wooden clubs. This is just too inefficient: even working night and day, there's no way they can handle the quantities required.

In fact, many suitable small machines are lying around the developed world, having been superseded by newer and more sophisticated models.

A. Bruce Maunder

Traditional grain varieties have been selected over the centuries to fit the constellation of agronomic adaptability in diverse environments, and at the same time have optimum milling, food quality, and storage properties. Most of the recent improved varieties from breeding programs in Africa yield grain that is poorly developed, headbug damaged, and chaffy when harvested from stressed environments. Such grain lends itself to high storage losses, low decortication yields, poor food quality, and poor seedling vigor. That the farmers don't adopt those varieties should not be a surprise. Cereal grain yield in Africa is the amount of nutrient per hectare that finally makes its way to the human stomach as food and to the animal stomach as feed. It is our challenge to start measuring that.

J.F. Scheuring and M. Haïdara

Everybody wants to help the poorest of the poor. However, when it comes the reality of applying modern knowledge it is often logistically impossible. To create a new variety—even of a well-understood crop like wheat—can easily take a decade of dedication and perhaps a million dollars of support. It is therefore clearly impractical to reach, individually, the thousands of different subsistence regions, each with its likes and dislikes, needs and desires, climates and conditions.

Noel Vietmeyer

There is a need to strengthen the links between sorghum and millet breeders and the food scientists, home economists, and other scientists involved in postproduction systems and the commercialization of sorghum and millet end products.

S. Vogel and M. Graham

Agronomy

When the aim is to improve a crop, one has also to improve the cropping system and the management of the fields (in terms of plant population, plant protection, soil fertility, etc.). The yield of any crop is very often related to the degree of intensification of the farming system. Therefore if we remain within the context of a traditional farming system or a slightly improved farming system, the agronomists and the breeders should not aim at achieving high dry-seeds yield; rather they should define the adaptive potentialities of the local varieties and try to utilize these to their maximum.

J.P. Baudoin

Despite the tremendous increases in food production in Asia, the Middle East, and parts of Latin America in recent years, agriculturalists

today face even greater production challenges to feed future generations. New Green Revolutions must occur in the more marginal production areas of Asia, sub-Sahara Africa, and parts of Latin America. These areas are generally rain-fed environments that suffer from moisture and temperature stresses, soil fertility problems, diseases and pests, and other difficult production conditions.

Norman E. Borlaug

For arid and semiarid regions with their variable and unpredictable climate breeders should select cultivars that can yield moderately well over a wide climatic spectrum and low agricultural inputs. Maybe the local farmers growing a mixture of cultivars in a field have the right idea!

Gerald E. Wickens

Sorghum

Sorghum is an excellent example of a low-input grain crop that has tremendous potential to meet the needs of an increasing demand for lower input, sustainable solutions to the world's agricultural production problems. Its present adaptation to marginal production areas and its lack of research input to increase its response to external inputs guarantees its better fit into any future agricultural production systems. Its wide, untapped genetic variability found in landraces and its wild an weedy relatives lend tremendous genetic wealth to increase its productivity in these more sustainable systems.

Paula J. Bramel-Cox

Far more attention needs to be paid to sorghum as a human food. In temperate zones the staple grain is wheat, but many of the developing tropical countries cannot grow wheat, and the strain on their financial resources of importing this grain on any scale would be great. They must, of necessity, grow most of their own food grains. Rice is a good grain type in areas where it can be grown. Maize is a valuable grain, but it shows a narrower range of variation in grain type than does sorghum, and cannot be grown everywhere. Of the tropical grains, the one most likely to repay research is sorghum, because it has so much variation in which to work. It should prove possible to develop sorghum grains of a better standard than any present-day tropical grains.

Hugh Doggett

Our responsibility is to develop even more stable and higher yielding [sorghum] cultivars from this wealth of diversity by making the

appropriate collections from dissimilar climates and recombining them into more widely adapted improved types useful to the world's people.

Fred R. Miller

The profuse branching and wide distribution of the root system is one of the main reasons why the sorghums are so markedly drought resistant. Other factors are however of importance. In the first place the plant above ground grows slowly until the root system is well established. Secondly, the system has to supply a leaf area which is approximately half the leaf area of maize. Thirdly, the low transpiration rate must influence the water demands. Finally, the plant can remain dormant during a prolonged drought and thereafter recontinue its development.

Hector (1936)

Appendix F

References and Selected Readings

AFRICAN RICE

Buddenhagen, I.W. and G.J. Persley, eds. 1978. *Rice in Africa: Proceedings of a Conference Held at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, 7-11 March 1977.* Academic Press, New York. 356 pp.

Carney, J.A. 1993. From hands to tutors: African expertise in the South Carolina rice economy. *Agricultural History* 67(3): 1-30.

Clayton, W.D. 1968. West African wild rice. *Kew Bulletin* 21:487-488.

Clement, G. and K. Goli. 1987. Yield capacity of *Oyzra glaberrima* as an upland crop. *L'Agronomie Tropicale* 42(4):275-279.

Fatokun, C.A., A.F. Attere, and H.R. Chheda. 1986. Variation in inflorescence characteristics of African rice (*Oryza glaberrima* Steud.). *Beitraefe zür Tropischen Landwirtschaft und Veterinaermedizin* 24(2):153-159.

Ghesquiere, A. 1985. Evolution of *Oryza longistaminata.* Pp. 15-25 in *Rice Genetics.* International Rice Research Institute (IRRI), Los Baños.

Jusu, M.S. and S.S. Monde. 1990. *Panicle and grain characters of some glaberrima cultivars in Sierra Leone.* International Rice Research Newsletter 15(3):5-6.

Leung, Woot-tseun, W., F. Busson, and C. Jardin. 1968. *Food Composition Table for Use in Africa.* U.S. Department of Health, Education, and Welfare and the Food and Agriculture Organization of the United Nations (FAO). Bethesda, Maryland.

Miezan, K., M.A. Choudhury, A. Ghesquiere, and G. Koffi. 1986. The use of *Oryza sativa* and *Oryza glaberrima* in West African farming systems. Pp. 213-218 in *Progress in Upland Rice Research.* Second International Upland Rice Conference, Jakarta, Indonesia, March 4-8, 1985. IRRI, Manila.

Morishima, H. and H.I. Oka. 1979. Genetic diversity in rice populations of Nigeria: influence of community structure. *Agro-Ecosystems* 5:263-269.

Netting, R. McC., D. Cleveland, and F. Stier. 1980. The conditions of agricultural intensification in the West African Savannah. Pages 187-505 in S.P. Reyna, ed.. *Sahelian Social Development.* USAID, Abidjan. (especially the section entitled "Interior Niger Delta of Mali")

Ogbe, F.M.D. 1993. Lost crops of Nigeria: West African rice. Pp. 71-94 in J.A. Okojie and D.U.U. Okali, eds., *Lost Crops of Nigeria: Implications for Food Security.* Conference Proceedings Series No. 3. University of Agriculture, Abeokuta, Nigeria.

Ogbe, F.M.D. and J.T. Williams. 1978. Evolution in indigenous West African rice. *Economic Botany* 32(1):59-64.

Oka, H.I. 1975. Mortality and adaptive mechanisms of *Oryza perennis* strains. *Evolution* 30:380-392.

Oka, H.I. 1977. Genetic variations of *Oryza glaberrima:* their survey and evaluation. Pp. 77-86 in *IRAT [Institut de Recherches Agronomiques Tropicales et des cultures vivrières] -ORSTOM [Institut Français de Recherche Scientifique pour le Développement en Cooperation de Montpellier] Meeting on Africa Rice Species.* Paris, 25-26 January 1977. IRAT-ORSTOM, Paris.

Oka, H.I. 1988. Origin of cultivated rice. In *Developments in Crop Science 14.* Japan Scientific Societies Press. Tokyo Elsevier, Amsterdam. 254 pages.

Pernes, J. 1984. Les riz. In *Gestion des Ressources Génétiques des Plantes.* Volume 1, Monographies (212 pp.). Volume 2, Manuel (346 pp.). Technique et documentation. Available from Lavoisier, 11 rue Lavoisier, 75384 Paris cedex 08, France.

Portères, R, 1956, Taxonomie agrobotanique des riz cultivés *O. sativa Linné et O. glaberrima* Steudel. *Compilations d'articles du JATBA.* Museum National d'Histoire Naturelle, Paris.

Portères, R. 1956. *Journal d'Agriculture Tropical et de Botanique Appliquées* 3:341, 541, 627, 821.
Richards, P. 1986. *Coping with Hunger: Hazard and Experiment in a West African Rice-Farming, System.* Allen and Unwin, London.
Sano, Y., T. Fujii, S. Iyama, Y. Hirota, and K. Komagata. 1981. Nitrogen fixation bacteria in the rhizosphere of cultivated and wild rice strains *Orzya glaberrima, Oryza perennis, Oryza punctata. Crop Science* 21(5):758-761.
Sano, Y., R. Sano, and H. Morishima. 1984. Neighbor effects between two co-occurring rice species, *Oryza sativa* and *O. glaberrima. Journal of Applied Ecology.* 21:245-254.
Schreurs, W. 1988. Les experiences en riz flottant dur project FENU a Tombouctou. FENU MLI/83/006, FAO, PNUD MLI/84/009, Tombouctou. (Copies available from author, see Appendix G.)
Thom, D.J. and J.C. Wells. 1987. Farming systems in the Niger inland delta, Mali. *The Geographic Review* 77(3):328-342.
Toure, A.I., M.A. Choudhury, M. Goita, S. Koli, and G.A. Paku. 1982. Grain yield and yield components of deep-water rice in West Africa. Pp. 103-112 in *Proceeding of the 1981 International Deep-water Rice Workshop, Bangkhen, Thailand.* IRRI, Laguna. Philippines.
Treca, B. 1987. Bird damage in floating rice in Mali. *Journal d'Agriculture Traditionnelle et de Botanique Appliquées* 34:153-170.
Vallee, G. and H.H. Vuong. 1978. Floating rice in Mali. In I.W. Buddenhagen and G.J. Persley, eds., *Rice in Africa.* Academic Press, London.
Yabuno, T. 1981. The transfer of a gene for glutinous endosperm to *Oryza glaberrima* Steud. from a japonica variety of *Oryza sativa* L. *Euphytica* 30(3):867-873.

FINGER MILLET

Appa Rao, S., L.R. House, and S.C. Gupta. 1989. *Review of Sorghum, Pearl Millet, and Finger Millet Improvement in SADCC [Southern Africa Development Coordination Council] Countries.* SACCAR/International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Bulawayo, Zimbabwe, 170 pp.
Barbeau, W.E. and K.W. Hilu. 1993. Protein, calcium, iron, and amino acid content of selected wild and domesticated cultivars of finger millet. *Plant Foods for Human Nutrition* 43(2):97-104.
Engels, J.M.M., J.G. Hawkes, and M. Worede, eds. 1991. *Plant Genetic Resource of Ethiopia.* Cambridge University Press, Cambridge, UK. 383 pp.
Flack, E.N., W. Quak, and A. von Diest. 1987. A comparison of the rock phosphate mobilizing capacities of various crop species. *Tropical Agriculture (UK)* 64(4):347-352.
Gupta, S.C. and J.N. Mushonga. 1994. Registration of 'SDEY 87001' finger millet. *Crop Science* 34 (2):536.
Hiremath, S.C. and S.S. Salimath. 1992. The 'A' genome donor of *Eleusine coracana* (L.) Gaertn. (Gramineae). *Theoretical and Applied Genetics* 84(5/6):747-754.
Kono, Y., A. Yamauchi, T. Nonoyama, and J. Tatsumi. 1988. Comparison of growth responses of summer cereals with special reference to waterlogging and rooting ability. *Japanese Journal of Crop Science* 57(2):321-331.
Marathee, J.P. Structure & characteristics of world millet economy. 1993. Pp. 159-178 in K.W. Riley, S.C. Gupta, A. Seetharam, and J.N. Mushonga, eds., *Advances in Small Millets.* Proceedings of an International Development Research Centre/ICRISAT conference. Oxford International Book House, New Delhi.
Mtebe, K., B.K. Ndabikunze, N.T.A. Bangu, and E. Mwemezi. 1993. Effect of cereal germination on the energy density of togwa. *International Journal of Food Sciences and Nutrition* 44(3): 175-180.
Pius, J., L. George, S. Eapen, and P.S. Rao. 1994. Evaluation of somaclonal and mutagen induced variation in finger millet. *Plant Breeding* 112(3):239-243.
Purseglove, J.W. 1972. *Tropical Crops: Monocotyledons. Volumes I and II.* Longman Scientific and Technical, Harlow, Essex, UK; John Wiley, New York. 607 pp.
Rachie, K.O. and L.V. Peters. 1977. *The Eleusines: A Review of the World Literature.* ICRISAT, Hyderabad, India. 179 pp.
Rai, R. 1991. Isolation, characterization and associative N-fixation of acid-tolerant *Azospirillum brasilense* strains associated with *Eleusine coracana* in low pH-Al-rich acid soil. *Developments in Plant and Soil Sciences* 45:663-671.
Riley, K.W., S.C. Gupta, A. Seetharam, and J.N. Mushonga, eds. 1993. *Advances in Small Millets.* Proceedings of an International DevelopmentResearch Centre (IDRC)/ICRISAT conference . Oxford International Book House, New Delhi.

Seetharam, A., K.W. Riley, and G. Harinarayana, eds. 1989. *Small Millets in Global Agriculture: Proceedings of the First International Small Millets Workshop, Bangalore, India, October 29-November 2, 1986.* Oxford & IBH Publishing Company, New Delhi. 392 pp.

Serna-Saldivar, S.O., C.M. McDonough, and L.W. Rooney. 1990. The millets. Pp. 271-300 in K.J. Lorenz and K. Kulp, eds., *Handbook of Cereal Science and Technology,* Dekker, New York.

Shankara, R., N.G. Malleshi, H. Krishnamurthy, M.N. Narayana, and H.S.R. Desikachar. 1985. Development of mini grain mill for dehusking and grinding of cereals. *Journal of Food Science Technology* 22:91.

Somasekhara, Y.M., S. Viswanath, T.B. Anilkumar. 1991. Evaluation of finger millet [*Eleusine coracana* (L.) Gaertn.] cultivars for their reactions to blast (*Pyricularia grisea* Sacc.). *Tropical Agriculture* 68(3):231-234.

Somasekhara, Y.M., S. Viswanath, and T.B. Anilkumar. 1992. Screeningof finger millet (*Eleusine coracana*) cultivars for multiple disease resistance . *Tropical Agriculture* 69(3):293-295.

Tewari, L., B.N. Johri, and S.M. Tandon. 1993. Host genotype dependency and growth enhancing ability of VA-mycorrhizal fungi for *Eleusine coracana* (finger millet).*[World] Journal of Microbial Biotechnology* 9(2):191-195.

Vittal, K.P.R., K. Vijayalakshmi, and U.M. Bhaskara Rao. 1991. Effects of topsoil, rainfall, and fertilizer on finger millet on an alfisol in India. *Soil Science* 152(1):3-6.

FONIO (ACHA)

Baptist, N.G. and B.P.M. Perera. 1956. Essential amino-acids of some tropical cereal millets. *British Journal of Nutrition* 10:334-337.

Busson, F. 1965. *Plantes Alimentaires de l'Ouest African: Etude Botanique, Biologique et Chimique.* Les Presses de I'lmprimerie Leconte, Marseilles.

Carbiener, R., P. Jaeger, and F. Busson. 1960. Study of the protein fraction of fonio grain, *Digitaria exilis* (Kippist), Stapf., a protein exceptionally rich in methionine. Ann. *Nutrit. Alimentation Mem.* 14:165-169.

De Lumen, B.O., R. Becker, and P.S. Reyes. 1986. Legumes and a cereal with high methionine/ cysteine contents. *Journal of Agricultural and Food Chemistry* 34(2):361-364.

De Lumen, B.O., S. Thompson, and W.J. Odegard. 1993. Sulfur amino acid-rich proteins in acha *(Digitaria exilis),* a promising underutilized African cereal. *Journal of Agricultural and Food Chemistry* 41(7): 1045-1047.

Gbodi, T.A., N. Nwude, Y.O. Aliu, and C.O. Ikediobi. 1986. The mycoflora and some mycotoxins found in acha *(Digitaria exilis* Stapf.) in Plateau State, Nigeria. *Food and Chemical Toxicology* 24(4):339-342.

Harlan, J.R., J.M.J. de Wet, and A.B.L. Stemler. 1976. *Origins of African Plant Domestication.* Mouton Publishers, The Hague. 498 pp.

Jideani, I.A. 1990. Acha. *Digitaria exilis,* the neglected cereal. *Agriculture International* 42 (5):132-134.

Jideani, I.A. and J.O. Akingbala. 1993. Some physicochemical properties of acha (*Digitaria exilis* Stapf) and iburu *(Digitaria iburua* Stapf) grains. *Journal of the Science of Food and Agriculture* 63(3):369-374.

Oyenuga, V.A. 1968. *Nigeria's Foods and Feeding Stuffs (Their Chemistry and Nutritive Value* (third ed., rev.). Ibadan University Press. Ibadan, Nigeria. 99 pp.

Oyewole, O.B. and J.O. Akingbala. 1993. "Acha" (*Digitaria exilis*)*:* a little known cereal with high potential. Pp. 323-326 in J.A. Okojie and D.U.U. Okali, eds., *Lost Crops of Nigeria: Implications for Food Security.* Conference Proceedings Series No. 3. University of Agriculture, Abeokuta, Nigeria.

Porteres, R. 1955. Les céréales mineures du genre *Digitaria* en Afrique et en Europe. *Journal d'Agriculture Tropical et de Botanique Appliqée* 2:349-386, 477-510, 620-675.

Riley, K.W., S.C. Gupta, A. Seetharam, J.N. Mushonga, eds. 1993. *Advances in Small Millets.* Proceedings of an IDRC/ICRISAT conference. Oxford International Book House, New Delhi.

Temple, V.J. and J.D. Bassa. 1991. Proximate chemical composition of Acha (*Digitaria exilis*) grain. *Journal of the Science of Food and Agriculture* 56(4):561-563.

PEARL MILLET

Andrews, D.J. 1974. Responses of sorghum varieties to intercropping. *Experimental Agriculture* 10:57-63.

Andrews, D.J. and P.J. Bramel-Cox. In press. Breeding varieties for sustainable crop production in low input dryland agriculture in the tropics. Pages 211-223 in D.R. Buxton et al., eds. *International Crop Science I.* Proceedings of a Conference, Ames, Iowa, July 1993. CSSA, Madison, Wisconsin.

Andrews, D.J. and K.A. Kumar. 1992. Pearl millet for food, feed and forage. *Advances in Agronomy* 48:90-139.

Andrews, D.J., J.F. Rajewski, and K.A. Kumar. 1993. Pearl millet: a new feed grain crop. Pp. 198-208 in J. Janick and J.E. Simon, eds., *New Crops.* Purdue University Press, Lafayette, Indiana.

Annegers, J.F. 1973. Ecology of dietary patterns and nutritional status in West Africa 1: distribution of starchy staples. *Ecology of Food Nutrition* 2(2):107-119.

Annegers, J.F. 1973. The protein-calorie ratio of West African diets and their relationship to protein calorie malnutrition. *Ecology of Food Nutrition* 2(3):225-235.

Annegers, J.F. 1973. Seasonal foods shortages in West Africa. *Ecologyof Food Nutrition* 2 (4):251-257.

Annegers, J.F. 1974. Protein quality of West African foods. *Ecology of Food Nutrition* 3(2):125-130.

Appa Rao, S. 1987. Traditional food preparations of pearl millet in Asia and Africa. In J.R. Witcombe and S.R. Beckerman, eds., *Proceedings of the International Pearl Millet Workshop, 7-11 April, 1986.* ICRISAT, Patancheru.

Appa Rao, S., M.H. Mengesha, and V. Subramanian. 1982. Collection and preliminary evaluation of sweet-stalk pearl millet (*Pennistum*). *Economic Botany* 36:286-290.

Badi, S., B. Pedersen, L. Manowar, and B.O. Eggum. 1990. The nutritive value of new and traditional sorghum and millet foods from Sudan. *Plant Foods or Human Nutrition* 40:5-19.

Bationo, A., C.B. Christianson, and W.E. Baethgen. 1990. Plant density and nitrogen fertilizer effects on pearl millet production in Niger. *Agronomy Journal* 82(2):290-295.

Bationo, A., C.B. Christianson, and M.C. Klaij. 1993. The effectof crop residue and fertilizer use on pearl millet yields on Niger . *Fertilizer Research* 34(3):251-258.

Brunken, J.N., J.M.J. de Wet, and J.R. Harlan. 1977. The morphology and domestication of pearl millet. *Economic Botany* 31:163-174.

Bunting, A.H. 1984. Advancing agricultural production in Africa: a personal review. Pages 435-445 in D.L. Hawksworth, ed., *Advancing Agricultural Production in Africa.* Commonwealth Agricultural Bureaux, Farnham Royal, UK.

Burton, G.W. and J.B. Powell. 1968. Pearl millet breeding and cytogenetics. *Advances in Agronomy* 20:49-89.

Burton, G.W., W.W. Hanna, J.C. Johnson, Jr., D.B. Lenck, W.G. Monson, J.B. Powell, H.D. Wells, and N.W. Widstrom. 1977. Pleiotropic effects of the *tr* trichomology gene in pearl millet on transpiration, forage quality and pest resistance. *Crop Science* 17:613-616.

Burton, G.W. and B.K. Werner. 1991. Genetic markers to locate and transfer heterotic chromosome blocks for increased pearl millet yields. *Crop Science* 31(3):576-579.

Buxton, D.R. et al., eds. In press. *International Crop Science 1.* Proceedings of a Conference, Ames, Iowa, July 1993. CSSA, Madison, Wisconsin.

Council of Scientific and Industrial Research (CSIR). 1966. *The Wealth of India (volume 8).* Publications & Information Directorate, CSIR, New Delhi.

Curtis, D.L., G.W. Burton, and O.J. Webster. 1966. Carotenoids in pearl millet seed. *Crop Science* 6:300-301. (vitamin-A millets)

Geiger, S.C., A. Manu, and A. Bationo. 1992. Changes in a sandy Sahelian soil following crop residue and fertilizer additions. *Soil Science Society of America Journal* 56(1):172-177.

Hamon, S. 1993. *Le mil en Africque.* Proceedings of a meeting on millet (*Pennisetum glaucum* L.). Montpellier, France, 24-26 November, 1992. Institut Français de Recherche Scientifique pour le Développe en Coopération (ORSTOM), Montpellier. 283 pp.

Hanna, W.W. 1987. Utilization of wild relatives of pearl millet. In J.R. Witcombe and S.R. Beckerman, eds., *Proceedings of the International Pearl Millet Workshop, 7-11 April, 1986.* ICRISAT, Patancheru.

Hanna, W.W. 1990. Transfer of germ plasm from the secondary to the primary gene pool in *Pennisetum. Theoretical land Applied Genetics* 80(2):200-204.

Hill, G.M. and W.W. Hanna. 1990. Nutritive characteristics of pearl millet grain in beef cattle diets. *Journal of Animal Science* 68:2061-2066.

Hoseney, R.C. and E. Varriano-Marston. 1979. Pearl millet: its chemistry and utilization. Pages 461-494 in *Cereals for Food and Beverages,* G.E. Inglett and L. Munck, eds. Academic Press, New York.

Hoseney, R.C., D.J. Andrews, and H. Clark. 1987. Sorghum and pearl millet. Pages 397-456 in *Nutritional Quality of Cereal Grains: Genetics and Agronomic Improvement.* Agronomy Monograph No. 28. CSSA, 677 South Segoe Road, Madison, Wisconsin 53711.

Hoseney, R.C., E. Varriano-Marston, and D.A.V. Dendy. 1981. Sorghum and millets: anatomy, composition, milling. Pp. 71-144 in Y. Pomeranz. ed., *Advances in Cereal Science and Technology, Volume IV* . American Association of Cereal Chemists (AACC), St. Paul, Minnesota.

Howarth, C.J. 1990. Heat shock proteins in sorghum and pearl millet; ethanol, sodium arsenite, sodium malonate and the development of thermotolerance. *Journal of Experimental Botany* 41 (228):877-883.

Hulse, J.H., E.M. Laing, and O.E. Pearson. 1980. *Sorghum and Millets: Their Composition and Nutritive Value.* Academic Press, New York. 997 pp.

International Sorghum/Millet (INTSORMIL) Collaborative Research Support Program/ICRISAT. 1987. *Proceedings of the International Pearl Millet Workshop.* ICRISAT, Patancheru. 278 pp.

INTSORMIL. 1990. *Annual Report 1990.* INTSORMIL, University of Nebraska, Lincoln. 246 pp.

INTSORMIL. 1991. *Annual Report 1991.* INTSORMIL, University of Nebraska, Lincoln. 256 pp.

Kumar, K.A. 1989. Pearl millet: current status and future potential. *Outlook on Agriculture* 18(2): 46-53.

Lambert, C. 1982. IRAT *[Institut de Recherches Agronomiques Tropicales et des cultures vivrières]* et l'amelioration de mil. *Agronomie Tropical.* 38:78-88.

Mahalakshmi, V., F.R. Bidinger, K.P. Rao, and D.S. Raju. 1992. Performanceand stability of pearl millet topcross hybrids and their variety pollinators . *Crop Science* 32(4):928-932.

Marathee, J.P. Structure & characteristics of world millet economy. 1993. Pp. 159-178 in K.W. Riley, S.C. Gupta, A. Seetharam, and J.N. Mushonga, eds., *Advances in Small Millets.* Proceedings of an IDRC ICRISAT conference. Oxford International Book House, New Delhi.

Matlon, P.J. 1990. Improving productivity in sorghum and pearl millet in semi-arid Africa. *Food Research Institute Studies* 22(1):1-43.

Mohammed, M.S. and M.D. Clegg. 1993. Pearl millet-soybean rotation and nitrogen fertilizer effects on millet productivity. *Agronomy Journal* 85(5):1009-1013.

Niangodo, O. and B. Ouendeba. 1987. Varietal improvement of pearl millet in West Africa. Pp. 95-105 in J.R. Witcombe and S.R. Beckerman, eds., *Proceedings of the International Pearl Millet Workshop. 7-11 April, 1986.* ICRISAT, Patancheru.

Obizoba, I.C. and J.V. Atii. 1994. Evaluation of the effect of processing techniques on the nutrient and antinutrient contents of pearl millet (*Pennisetum glaucum*) seeds. *Plant Foods for Human Nutrition* 45 (1):23-34.

Oendeba, B., G. Ejeta, W.E. Nyquist, W.W. Hanna, and A. Kumar. 1993. Heterosis and combining ability among African pearl millet landraces. *Crop Science* 33(4):735-739.

Pantulu, J.V. and M. Krishna Rao. 1982. Cytogenetics of pearl millet. *Theoretical and Applied Genetics* 61:1-17.

Rachie, K.O. and J.V. Majmudar. 1980. *Pearl Millet.* Pennsylvania State University Press. University Park, Pennsylvania. 307 pp.

Read, J.C. and E.C. Bashaw. 1974. Intergeneric hybrid between pearl millet and buffel grass. *Crop Science* 14:401-403.

Serna-Saldivar, S.O., C.M. McDonough, and L.W. Rooney. 1990. The millets. Pp. 271-300 in K.J. Lorenz and K. Kulp, eds., *Handbook of Cereal Science and Technology.* Dekker, New York.

Singh, P., Y. Singh, B.O. Eggum, K.A. Kumar, and D.J. Andrews. 1987. Nutritional evaluation of high protein genotypes in pearl millet. *Journal of the Science of Food and Agriculture* 38:41-48.

Smith, R.L., L.S. Jensen, C.S. Hoveland, and W.W. Hanna. 1989. Use of pearl millet, sorghum, and triticale grain in broiler diets. *Journal of Production Agriculture* 2:78-82.

Tostain, S. 1992. Enzyme diversity in pearl millet (*Pennisetum glaucum* L.). 3. Wild millet. *Theoretical and Applied Genetics* 83(6/7):733-742.

PEARL MILLET, SUBSISTENCE TYPES

International Development Research Centre (IDRC). 1979. *Sorghum and Millet: Food Production and Use.* Report of a workshop held in Nairobi, Kenya, July 4-7, 1978. S. Vogel and M. Graham, eds. Report No. IDRC-123e. IDRC, Ottawa, Canada

Wendt, J.W., A. Berrada, M.G. Gaoh, and D.G. Schulze. 1993. Phosphorus sorption characteristics of productive and unproductive Niger soils. *Soil Science Society of America Journal* 57(3):766-773.

Zaongo, C.G.L., L.R. Hossner, and C.W. Wendt. 1994. Root distribution, water use, and nutrient uptake of millet and grain sorghum on West Africa soils. *Soil Science* 157(6):379-388.

PEARL MILLET, COMMERCIAL TYPES

Bramel-Cox, P.J., K. Anand kumar, J.H. Hancock, and D.J. Andrews. In press. Sorghum and millets for forage and feed. In D.A.V. Dendy, ed., *Sorghum and Millets: Chemistry and Technology.* AACC, St. Paul, Minnesota.

D.A.V. Dendy, ed., In press. *Sorghum and Millets: Chemistry and Technology.* AACC, St. Paul, Minnesota.

Hoseney, R.C. and E. Varriano-Marston. 1980. Pearl millet: its chemistry and utilization. Pp. 462-494 in G.E. Inglett and L. Munck, eds. *Cereals for Food and Beverages: Recent Progress in Cereal Chemistry and Technology.* Proceedings of an international conference, August 13-17, 1979, Copenhagen, Denmark. Academic Press, New York.

Hoseney, R.C., E. Varriano-Marston, and D.A.V. Dendy. 1981. Sorghum and millets: anatomy, composition, milling. Pp. 71-144 in Y. Pomeranz, ed., *Advances in Cereal Science and Technology, Volume IV.* AACC, St. Paul, Minnesota.

Hulse, J.H., E.M. Laing, and O.E. Pearson. 1980. *Sorghum and Millets: Their Composition and Nutritive Value.* Academic Press, New York. 997 pp.

Kumar, K.A., S.C. Gupta, and D.J. Andrews. 1983. Relationship between nutritional quality characters and grain yield in pearl millet. *Crop Science* 23:232-235.

Rachie, K.O. and J.C. Majmudar. 1980. Pearl Millet. Pennsylvania State University Press, University Park, Pennsylvania. 307 pp.

SORGHUM

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Andrews, D.J. 1972. Intercropping with sorghum in Nigeria. *Experimental Agriculture* 8:139-150.

Andrews, D.J. 1974. Responses of sorghum varieties to intercropping. *Experimental Agriculture* 10:57-63.

Andrews, D.J. and P.J. Bramel-Cox. 1993. Breeding varieties for sustainable crop production in low input dryland agriculture in the tropics. Pages 211-223 in D.R. Buxton et al., eds. *International Crop Science I.* Proceedings of a Conference, Ames, Iowa, July 1993. CSSA, Madison, Wisconsin.

Bramel-Cox, P.J., K. Anand kumar, J.H. Hancock, and D.J. Andrews. In press. Sorghum and millets for forage and feed. In D.A.V. Dendy, ed., *Sorghum and Millets: Chemistry and Technology.* AACC, St. Paul, Minnesota.

Brand, T.S., H.A. Badenhorst, and F.K. Siebrits. 1990. The use of pigs both intact and with ileorectal anastomosis to estimate the apparent and true digestibility of amino acids in untreated, heat-treated and thermal-ammoniated high-tannin grain sorghum. *South African Journal of Animals Science* 20(4):223-228.

Bunting, A.H. 1984. Advancing agricultural production in Africa: a personal review. Pages 435-445 in D.L. Hawksworth, ed., *Advancing Agricultural Production in Africa.* Commonwealth Agricultural Bureaux, Farnham Royal, UK.

Buxton, D.R. et al., eds. In press. *International Crop Science I.* Proceedings of a Conference, Ames, Iowa, July 1993. CSSA, Madison. Wisconsin.

de Milliano, W.A.J., R.A. Frederiksen, and G.D. Bengston, eds. 1992. *Sorghum and Millet Diseases: A Second World Review.* ICRISAT, Patancheru. 370 pp.

Dendy, D.A.V., ed. In press. *Sorghum and Millets: Chemistry and Technology.* AACC. St. Paul, Minnesota.

DeWalt, B.R. 1985. Mexico's second Green Revolution: food for feed. *Mexican Studies/Estudios Mexicanos* 1(1):29-60.

Doggett, H. 1988. *Sorghum.* Longmans. London. 515 pp.

Doumbia, M.D., L.R. Hossner, and A.B. Onken. 1993. Variable sorghum growth in acid soils of subhumid West Africa. *Arid Soil Research and Rehabilitation* 7(4):335-346.

Eggum, B.O. 1990. Importance of sorghum as a food in Africa. Pp. 222-228 in G. Ejeta, E.T. Mertz, L. Rooney, R. Schafert, and J. Yohe, eds., *Sorghum Nutritional Quality: proceedings of an international conference held February 26-March 1, 1990.* Purdue University, West Lafayette, Indiana.

Einhellig, F.A. and I.F. Souza. 1992. Phytotoxicity of sorgoleone found in grain sorghum root exudates. *Journal of Chemical Ecology* 18(1): 1-11.

Ejeta, G. 1983. *Hybrid Sorghum Seed for Sudan: Proceedings of a Workshop, November 5-8, 1993, Gezira Research Station, Sudan.* Agricultural Research Corporation, Wad Medani, Sudan.

Ejeta, G., E.T. Mertz, L. Rooney, R. Schaffert, and J. Yohe, eds. 1990. *Sorghum Nutritional Quality: proceedings of an international conference held February 26-March 1, 1990.* Purdue University, West Lafayette, Indiana.

Engels, J.M.M., J.G. Hawkes, and M. Worede, eds. 1991. *Plant Genetic Resources of Ethiopia.* Cambridge University Press, Cambridge, UK. 383 pp.

House, L.R. 1985. *A Guide to Sorghum Breeding.* 2nd edition. ICRISAT, India. 238 pp.

Howarth, C.J. 1990. Heat shock proteins in sorghum and pearl millet: ethanol, sodium arsenite, sodium malonate and the development of thermotolerance. *Journal of Experimental Botany* 41 (228):877-883.

Hulse, J.H., E.M. Laing, and O.E. Pearson. 1980. *Sorghum and the Millets: Their Composition and Nutritive Value.* Academic Press, New York. 997 pp.

ICRISAT. 1982. *Sorghum in the Eighties: Proceedings of the International Symposium on Sorghum.* November 2-7 1981. Patancheru, A.P. India. ICRISAT, Patancheru.

International Board for Plant Genetic Resources (IBPGR). 1976. *Proceedingsof the Meeting of the Advisory Committee on Sorghum and Millets Germplasm* . Rome. Mimeo.

IDRC. 1979. *Sorghum and Millet: Food Production and Use*. Report of a workshop held in Nairobi, Kenya, 4-7 July 1978. S. Vogel and M. Graham, eds. IDRC, Ontario, Canada.

IRAT. 1978. L'IRAT et l'amelioration due sorgho. *Agronomie Tropicale* 32:279-318.

INTSORMIL/ICRISAT. 1987. *Proceedings of the International Pearl Millet Workshop.* ICRISAT. Patancheru. 278 pp.

Leng, E.R. 1982. Status of sorghum production as compared to other cereals. Pages 25-32 in *Sorghum in the Eighties: Proceedings of the International Symposium on Sorghum.* November 2-7 1981. Patancheru, A.P. India. ICRISAT, Patancheru.

Lopez-Pereira, M.A., et al. 1990. New agricultural technologies in Honduras: an economic evaluation of new sorghum cultivars in southern Honduras. *Journal for Farming System Research and Extension* 1(2):81-103.

Matlon, P.J. 1990. Improving productivity in sorghum and pearl millet in semi-arid Africa. *Food Research Institute Studies* 22(1): 1-43.

Quinby, J.R. 1971. *A Triumph of Research . . . Sorghum in Texas.* Texas A&M University Press, College Station. 28 pp.

Quinby, J.R. 1974. *Sorghum Improvement and the Genetics of Growth.* Texas A&M University Press. College Station, Texas. 108 pp.

Rooney, L.W., A.W. Kirleis, and D.S. Murty. 1986. Traditional foods from sorghum: their production, evaluation, and nutritional value. Pages 317-353 in *Advances in Cereal Science and Technology volume 3.* AACC, St. Paul, Minnesota.

Serna-Saldivar, S.O., C.M. McDonough, and L.W. Rooney. 1990. The millets. Pp. 271-300 in K.J. Lorenz and K. Kulp, eds., *Handbook of Cereal Science and Technology.* Dekker, New York.

Van de Venter, H.A. and W.H. Lock. 1992. An investigation of heat-shock and thermotolerance induction responses as indices of seed vigour in grain sorghum [*Sorghum bicolor* (L.) Moench.]. *Plant Varieties and Seeds* 5(1): 13-18.

Wenzel, W.G. 1991. The inheritance of drought resistance characteristics in grain sorghum seedlings. *South African Journal of Plant and Soil* 8(4):169-171.

Zaongo, C.G.L., L.R. Hossner, and C.W. Wendt. 1994. Root distribution, water use, and nutrient uptake of millet and grain sorghum on West Africa soils. *Soil Science* 157(6):379-388.

SORGHUM, SUBSISTENCE TYPES

Carr, S.J. 1989. *Technology for Small-scale Farmers in Sub-Saharan Africa.* Technical Paper No. 109, World Bank, Washington, D.C. 106 pp.

DeWalt, B.R. 1985. Microcosmic and macrocosmic processes of agrarian change in southern Honduras: the cattle are eating the forests. Pages 165-185 in *Micro and Macro Levels of Analysis in Anthropology: Issues in Theory and Research.* Westview Press, Boulder, Colorado and London.

International Sorghum/Millet (INTSORMIL) Collaborative Research Support Program. 1990. *Annual Report 1990.* INTSORMIL, University of Nebraska, Lincoln. 246 pp.

INTSORMIL. 1991. *Annual Report 1991.* INTSORMIL, University of Nebraska, Lincoln. 256 pp.

Mukuru, S.Z. 1990. Traditional food grain processing methods in Africa. Pp. 216-221 in G. Ejeta. E.T. Mertz, L. Rooney, R. Schaffert, and J. Yohe, eds., *Sorghum Nutritional Quality: proceedings of an international conference held February 26-March 1, 1990.* Purdue University. WestLafayette, Indiana .

Rao, N.G.P. 1982. Transforming traditional sorghums in India. Pages 39-59 in *Sorghum in the Eighties: Proceedings of the International Symposium on Sorghum.* November 2-7 1981. ICRISAT, Patancheru.

SORGHUM, COMMERCIAL TYPES

Bennett, W.F., B.B. Tucker, and A.B. Maunder. 1990. *Modern Grain Sorghum Production.* Iowa State University Press, Ames. 169 pp.

DeWalt, B.R. and D. Barkin. 1987. Seeds of change: the effects of hybrid sorghum and agricultural modernization in Mexico. Pages 138-161 in H.R. Bernard and P.J. Pelto, eds., *Technology and Social Change,* 2nd ed. Waveland Press, Prospect Heights, Illinois. 393 pp.

Faure, J. 1988. Sorghum utilization in pasta production. Paper presented in the International Workshop on Policy and Potential Relating to Uses of Sorghum and Millets. June 8-12, 1988. SADCC/ICRISAT. Bulawayo, Zimbabwe.

ICRISAT. 1990. *Industrial Utilization of Sorghum: Summary of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria.* December 4-6, 1989, Kano Nigeria. ICRISAT, Patancheru, Andhra Pradesh, India. 59 pp.

SORGHUM, SPECIALTY TYPES

Gupta, S.C., J.M.J. dewet, and J.R. Harlan. 1978. Morphology of *Saccharum -Sorghum* hybrid derivatives. *American Journal of Botany* 65:936-942. (sorghum relatives)

Gupta, S.C., J.R. Harlan, and J.M.J. dewet. 1978. Cytology and morphology of a tetraploid *Sorhum* population recovered from a *Saccharum = Sorghum* hybrid. *Crop Science* 18:879-883. (sorghum relatives)

Haggblade, S. and W.H. Holzapfel. 1989. Industrialization of Africa's indigenous beer brewing. Pages 191-283 in K.H. Steinkraus, ed., *Industrialization of Indigenous Fermented Foods,* Dekker, New York. (beer sorghums)

Hahn, D.H., L.W. Rooney, and C.F. Earp. 1984. Tannins and phenols of sorghum. *Cereal Foods World* 29(12):776-779. (tannin-free sorghums)

Jabri, A., R. Chaussat, M. Jullien, and Y. le Deunff. 1989. Callogenesisand somatic embryogenesis in leaf portions of three varieties of sorghum with and without tannins . *Agronomie* (France) 9 (1):101-107. (tannin-free sorghums)

Novellie, L. 1982. Fermented beverages. In L.W. Rooney and D.S. Murty. eds . *Proceedings, International Grain Sorghum Quality Workshop.* ICRISAT, Patancheru.

Novellie, L. and P. De Schaepdrijver. 1986. Modern developments in traditional African beers. Pages 73-157 in M.R. Adams, ed., *Progress in Industrial Microbiology, Vol. 23.* Elsevier, Amsterdam. (beer sorghums)

Thorat, S.S., P.N. Satwadhar, D.N. Kulkarni, S.D. Choudhari, and U.M. Ingle. 1990. Varietal differences in popping quality of sorghum grains. *Journal of Maharashtra Agricultural Universities* 15(2):173-175. (popping sorghums)

SORGHUM, FUEL AND UTILITY TYPES

Clegg, M.D., H.J, Gorz, J.W. Maranville, and F.A. Haskins. 1986. Evaluation of agronomic and energy traits of Wray sweet sorghum and the N39x Wray hybrid. *Energy Agriculture* 6:49-54.

Coleman, O.H. 1970. Syrup and sugar from sweet sorghum. Page 438 in J.S. Wall and W.M. Ross, eds., *Sorghum Production and Utilization.* Avi Publishing Company, Westport, Connecticut.

Cundiff, J.S. and D.H. Vaughan 1986. Sweet sorghum for ethanol industry for the Piedmont. Virginia Agricultural Experiment Station Bulletin 0096-6088, 86-9. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Gascho, G.J., R.L. Nichols, and T.P. Gaines. 1984. Growing sweet sorghum as a source of fermentable sugars for energy. Research Bulletin 315. University of Georgia Experiment Station, Athens, Georgia.

Gas Research Institute. 1982. *SNG [synthetic natural gas] from land-based biomass: 1981 program final report.* Gas Research Institute, 8600 West Bryn Mawr Avenue, Chicago, IL 60631, USA. III pp.

Gibbons, W.R., C.A. Westby, and T.L. Dobbs. 1986. Intermediate-scale, semicontinuous solid-phase fermentation process for production of fuel ethanol from sweet sorghum. *Applied Environmental Microbiology* 51(1): 115-122.

Hills, F.J., R.T. Lewellen, and I.O. Skoyen. 1990. Sweet sorghum cultivars for alcohol production. *California Agriculture* 44(1):14-16.

Kapocsi, I., J. Lezanyi, and B. Kevacs. 1983. Utilization of sweet sorghum for alcohol production. *Internationale Zeitschrift fuer Landwirtschaften* 5:441-443.

Kresovich, S., R.E. McGee, L. Panella, A.A. Reilley, and F.R. Miller. 1987. Application of cell and tissue culture techniques for the genetic improvement of sorghum, *Sorghum bicolor* (L.) Moench: progress and potential. *Advances in Agronomy* 41:147-170.

Kresovich, S. and D.M. Broadhead. 1988. Registration of 'Smith' sweet sorghum. *Crop Science* 28 (1): 195.

Kresovich, S., F.R. Miller, R.L. Monk, R.E. Dominy, and D.M. Broadhead. 1988. Registration of 'Grassl' sweet sorghum. *Crop Science* 28(1) :194-195.

Lipinsky, E.S., D.R. Jackson, S. Kresovich, M.F. Arthur, and W.T. Lawhon. 1979. Carbohydrate Crops as a Renewable Resource for Fuels Production, Vol. 1: Agricultural research. Battelle Memorial Institute Columbus Laboratories, Columbus, Ohio 43201, USA

Lueschen, W.E., D.H. Putnam, B.K. Kanne, and T.R. Hoverstad. 1991. Agronomic practices for production of ethanol from sweet sorghum. *Journal of Production Agriculture* 4(4):619-625.

McClure, T.A., M.F. Arthur, S. Kresovich, and D.A. Scantland. 1980. Sorghums—viable biomass candidates for fuel alcohol production. Volume 1, pp. 123-130 in *Proceedings of the IV International Symposium on Alcohol Fuels Technology, Guaruja, São Paulo, Brazil, 5-8 Oct. 1980.* Instituto de Pesquisas Tecnológicas do Estado de São Paulo, São Paulo.

Miller, F.R. and G.G. McBee. 1993. Genetics and management of physiologic systems of sorghum for biomass production. Pages 41-49 in *Methane from Biomass: Science and Technology.* Biomass and Bioenergy, Vol. 5, No. 1. Pergamon Press, Ltd., Oxford.

Morris, D.J. and I. Ahmed. 1992. *The carbohydrate economy: making chemicals and industrial materials from plant matter.* Institute for Local Self Reliance, Washington, DC.

Rajvanshi, A.K., R.M. Jorapur, and N. Nimbkar. 1989. *VITA News.* October. Pp. 7-8.

Ricaud, R. and A. Arceneaux. 1990. Sweet sorghum research on biomass and sugar production in 1990. Pp. 136-139 in *Report of Projects.* Louisiana Agricultural Experiment Station, Department of Agronomy, Louisiana State University, Baton Rouge, Louisiana.

Schaffert, R.E. 1988. Sweet sorghum substrate for industrial alcohol. Paper presented in the International Workshop on Policy and Potential Relating to Uses of Sorghum and Millets. June 8-12, 1988. SADCC/ICRISAT. Bulawayo, Zimbabwe.

Schaffert, R.E. and L.M. Gourley. 1982. Sorghum as an energy source. Pages 605-623 in *Sorghum in the Eighties: Proceeding of the International Symposium on Sorghum.* November 2-7 1981. ICRISAT, Patancheru.

Smith, B.A. 1982. Sweet sorghum. Page 611 in I.A. Wolf, ed., *CRC Handbook of Processing and Utilization in Agriculture. Volume 2.* CRC Press, Boca Raton, Florida.

Weitzel, T.T., J.S. Cundiff, and D.H. Vaughan. 1986. Improvement of juice expression after separation of sweet sorghum pith from rind leaf. American Society of Agricultural Engineers Microfiche Collection No. 86-6579. American Society of Agricultural Engineers, St. Joseph, Michigan.

TEF

Ashenafi, M. 1994. Microbial flora and some chemical properties of ersho, a starter for teff (*Eragrostis tef*) fermentation. *[World] Journal of Microbial Biotechnology* 10(1):69-73.

Berhe, T., L.A. Nelson, M.R. Morris, and J.W. Schmidt. 1989. Inheritance of phenotypic traits in tef: I - lemma color, II - seed color, III -panicle form. *Journal of Heredity* 80:62-70.

Besrat, A., A. Admasu, and M. Ogbai. 1980. Critical study of the iron content of tef (*Eragrotis tef*). *Ethiopian Medical Journal* 18:45-52.

Cheverton, M.R. and N.W. Galwey. 1989. Ethiopian t'ef: a cereal confined to its centre of variability. Pages 235-238 in G.E. Wickens, N. Haq, and P. Day, eds., *New Crops for Food and Industry.* Chapman and Hall, London and New York.

FAO. 1988. *Traditional Food Plants.* Food and Nutrition Paper 42. FAO, Rome.

Huffragel, H.P. 1961. *Agriculture in Ethiopia* FAO. Rome. 484 pp.

Jones, G. 1988. Endemic crops plants of Ethiopia I: t'ef (*Eragrotis tef*). *Walia* 11:37-43.

Ketema, S. 1988. Status of small millets in Ethiopia and Africa. Pp. 6-15 in *Small Millet: Recommendations for a Network.* Proceedings of the Small Millets Steering Committee Meeting, Addis Ababa, Ethiopia, 7-9 October 1987. International Development Research Centre, Ottawa.

Ketema, S. 1991. Germplasm evaluation and breeding work on teff (*Eragrostis tef*) in Ethiopia. Pp. 323-328 in Engels, J.M.M., J.G. Hawkes, and M. Worede, eds. 1991, *Plant Genetic Resources of Ethiopia.* Cambridge University Press, Cambridge, UK. 383 pp.

Lester, R.N. and E. Bekele. 1981. Amino acid composition of the cereal tef and related species of *Eragrostis* (Gramineae). *Cereal Chemistry* 58:113-115.

Mamo, T. and K.S. Killham. 1987. Effect of soil liming and vesicular-arbuscular-mycorrhizal inoculation on the growth and micronutrient content of the teff plant. *Plant and Soil* 102:257-259.

Mamo, T. and J.W. Parsons. 1987. Phosphorus-micronutrient interactions in teff (*Eragrostis tef*). *Tropical Agriculture* 64:309-312.

Mamo, T. and J.W. Parsons. 1987. Iron nutrition of *Eragrostis tef* (teff). *Tropical Agriculture 64*:313-317.

Marathee, J.P. Structure & characteristics of world millet economy. 1993. Pp. 159-178 in K.W. Riley, S.C. Gupta, A. Seetharam, and J.N. Mushonga, eds., *Advances in Small Millets.* Proceedings of an IDRC/ICRISAT conference. Oxford International Book House, New Delhi.

Osuji, P.O. and B. Capper. 1992. Effect of age on fattening and body condition of draught oxen fed teff straw (*Eragrostis teff*) based diets. *Tropical Animal Health and Production* 24(2): 103-108.

Parker, M.L., M. Umeta, and R.M. Faulks. 1989. The contribution of flour components to the structure of injera, an Ethiopian fermented bread made from tef (*Eragrostis tef*). *Journal of Cereal Science* 10(2):93-104.

Riley, K.W., S.C. Gupta, A. Seetharam, J.N. Mushonga, eds. 1993. *Advances in Small Millets.* Proceedings of an IDRC/ICRISAT conference. Oxford International Book House, New Delhi.

Seetharam, A., K.W. Riley, and G. Harinarayana. 1989. *Small Millets in Global Agriculture.* IDRC, Ottawa, Canada. 392 pp.

Tadesse, E. 1969. *Tef* (*Eragrostis tef*): *cultivation, usage, and some of the known disease and insect pests, Part I.* Experiment Station Bulletin No. 60. College of Agriculture, Haile Sellasie I University, Dire Dawa, Ethiopia. 56 pp.

Tadesse, E. 1975. T'ef (*Eragrostis tef*) cultivars: morphology and classification Part II. Experiment Station Bulletin No. 66. College of Agriculture, Addis Ababa University, Dire Dawa, Ethiopia. 73 pp.

Tadesse, D. 1993. Study of genetic variation of landraces of teff (*Eragrostis tef* (Zucc.) Trotter) in Ethiopia. *Genetic Resources and Crop Evolution* 40(2):101-104.

Tefera, H., S. Ketema, and T. Tesemma. 1990. Variability, heritability and genetic advance in tef (*Eragrostis tef* (Zucc.) Trotter) cultivars. *Tropical Agriculture* 67(4):317-320.

Twidwell, E.K., A. Boe, and D.P. Casper. 1991. Teff: a new annual forage grass for South Dakota. Extension Extra 8071. South Dakota Cooperative Extension Service, Brookings, South Dakota.

Umeta. M. and R.M. Faulks. 1988. The effect of fermentation on the carbohydrates in *tef* (*Eragrostis tef*). *Food Chemistry* 27:181-189.

Westphal, E. and J.M.C. Westphal-Stevels. 1975. *Agricultural Systemsin Ethiopia* . Agricultural Research Reports 82b. Puduc, Wageningen. 278 pp.

Wolde-Gebriel, Z. 1988. Nutrition. In Zein Ahmed Zein and Helmut Kloos, eds., *The Ecology of Health and Disease in Ethiopia.* Ministry of Health, Addis Ababa.

OTHER CULTIVATED GRAINS

General

Harlan, J.R. 1986. *African Millets.* Food and Agriculture Organization of the United Nations (FAO). Rome

Harlan, J.R. 1989. Wild grass seed harvesting in the Sahara and Sub-Sahara of Africa. In *Foraging and Farming: the Evolution of Plant Exploitation,* D.R. Harris and G.C. Hillman, eds. Unwin-Hyman, London.

Emmer

Gasrataliev, G.S. 1982. Forms of *T. dicoccum* promising for southern Dagestan. *Bulletin of the N.I. Vavilov Institute of Plant Industry* 118:5-6.

Hakim, S., A.B. Damania, and M.Y. Moualla. 1992. Genetic variability in *Triticum dicoccum* Schubl. for use in breeding wheat for the dry areas. *FAO/IBPGR Plant Genetic Resources Newsletter* 88/89:11-15.

Mariam, G.H. and H. Mekbib. 1988. Agromorphological evaluation of *T. dicoccum. PGRC/E ILCA Germplasm Newsletter* 6-11.

Robinson, J. and B. Skovmand. 1992. Evaluation of emmer wheat and other Triticeae for resistance to Russian wheat aphid. *Genetic Resources and Crop Evolution* 39(3):159-163.

Barley

Endashaw Bekele. 1984. Relationships between morphological variance, gene diversity and flavonoid patterns in the land race populations of Ethiopian barley. *Hereditas* 100:271-294.

Engels, J.M.M., J.G. Hawkes, and M. Worede, eds. 1991. *Plant Genetics Resources of Ethiopia.* Cambridge University Press. Cambridge, UK. 383 pp.
Huffragel, H.P. 1961. *Agriculture in Ethiopia* FAO. Rome. 484 pp.
Munck, L. 1988. The importance of botanical research in breeding for nutritional quality characteristics in cereals. *Symbolae Botanicae Upsalienses* 28(3):69-78.
Nulugeta Negassa. 1985. Patterns of phenotypic diversity in an Ethiopian barley collection, and the Arsi-Bale Highland as a centre of Origin of barley. *Hereditas* 102:139-150.
Qualset, C.O. 1975. Sampling germplasm in a centre of diversity: an example of disease resistance in Ethiopian barley. Pages 81-96 in O.H. Frankel and J.G. Hawkes, eds., *Crop Genetic Resources for Today and Tomorrow.* Cambridge University Press, Cambridge.
Westphal, E. and J.M.C. Westphal-Stevels. 1975. *Agricultural Systems in Ethiopia.* Agricultural Research Reports 82b. Puduc, Wageningen. 278 pp.

Ethiopian oats

Baum, B.R. 1971. Taxonomic studies in *Avena abyssinica* and *Avenavaviloviana,* and some related species. *Canadian Journal of Botany* 49(12):2227-2232
Engels, J.M.M., J.G. Hawkes, and M. Worede, eds. 1991. *Plant Genetic Resources of Ethiopia.* Cambridge University Press, Cambridge, UK. 383 pp.
Ladizinsky, G. 1975. Oats in Ethiopia (*Avena barbata, Avena abyssinica,* cereal weeds). *Economic Botany* 29(3):238-241.

Guinea Millet

Harlan, J.R. 1986. *African Millets.* Food and Agriculture Organization of the United Nations (FAO). Rome

Kodo millet

De Wet, J.M.J., K.E. Prasada Rao, M.H. Mengesha, and D.E. Brink. 1983. Diversity in kodo millet, *Paspalum scrobiculatum. Economic Botany* 37(2):159-163.
Geervani, P. and B.O. Eggum. 1989. Effect of heating and fortification with lysine on protein quality of minor millets. *Plant Foods for Human Nutrition* 39(4):349-357.
Kapoor, P.N., S.P. Netke, and L.D. Bajpai. 1987. Kodo (*Paspalum scorbiculatum*) *as* a substitute for maize in chick diets. *Indian Journal of Animal Nutrition* 4(2):83-88.
Kaushik, S.K. and R.C. Gautam. 1985. Comparative performance of different millets at varying levels of nitrogen under dryland conditions. *Indian Journal of Agronomy* 30(4):509-511.
Ketema, S. 1988. Status of small millets in Ethiopia and Africa. Pp. 6-15 in *Small Millets: Recommendations for a Network.* Proceedings of the Small Millets Steering Committee Meeting. Addis Ababa, Ethiopia, 7-9 October 1987. International Development Research Centre, Ottawa.
Nayak, P. and S.K. Sen. 1991. Plant regeneration through somatic embryogenesis from suspension culture-derived protoplasts of *Paspalum scrobiculatum* L. *Plant Cell Reports* 10(6/7):362-365.
Sridhar, R. and G. Lakshminarayana. 1992. Lipid class contents and fatty acid composition of small millets: little (*Panicum sumatrense*), kodo (*Paspalum scrobiculatum*). and barnyard (*Echinocloa colona*). *Journal of Agricultural and Food Chemistry* 40(11):2131-2134.
Sudharshana, L., P.V. Monteiro, and G. Ramachandra. 1988. Studies on the proteins of kodo millet (*Paspalum scrobiculatum*). Journal *of the Science of Food and Agriculture* 42(4):315-323.

Wild Grains

Breman, H. and L. Diarra. 1989. Easy methods to follow the changes of vegetation in natural pastures in the Sahel. *Rapport CABO - Centre for Agrobiological Research* (*Netherlands*) *No.* 102. 40 pp.
Elberse, W.T. and H. Breman. 1990. Germination and establishment of Sahelian rangeland species. II. Effects of water availability. *Oecologia* 85(1):32-40. (*Eragrostis tremula,* kram-kram)
Harlan, J.R. 1989. Wild grass seed harvesting in the Sahara and Sub-Sahara of Africa. In D.R. Harris and G.C. Hillman, eds, *Foraging and Farming: the Evolution of Plant Exploitation.* Unwin-Hyman, London.

Kumar, A. 1976. Dry matter production and growth rates of three aridzone grasses in culture (*Dactyloctenium aegyptium, Cenchrus biflora and Cenchrus ciliaris*) . *Comparative Physiology and Ecology* 1(1):23-26. (Egyptian grass, kram-kram)

McKenzie, B. 1982. Resilience and stability of the grasslands of Transkei *Aristida. Themeda.* systems grazing. South Africa. *Proceedings of the Grasslands Society of South Africa* 17:21-24. (Drinn, *Themeda)*

Nicolaisen, J. 1963. *Ecology and Culture of the Pastoral Tuareg*. Copenhagen National Museum, Copenhagen.

Salih, O.M.. A.M. Nour and D.B. Harper. 1992. Nutritional quality of uncultivated cereal grains utilized as famine foods in western Sudan as measured by chemical analysis. *Journal of the Science of Food and Agriculture* 58:417-424. (Egyptian grass. kram-kram. Shama millet, wadi rice

Sharma, B.M. and A.O. Chivinge. 1982. Contribution to the ecology of *Dactyloctenium aegyptium* (L.) P. Beauv.: A nutritious fodder. Nigeria. *Journal of Range Management* 35(3):326-331. (Egyptian grass)

Siddiqui, K.A. 1987. Contribution of *Dactyloctenium aegyptium* (L.) Beauv. to bioreclamation of salt-affected soil. *Annals of Arid Zone* 26(4):301-303. (Egyptian grass)

United Nations Sudano-Sahelian Office (UNSO). 1990. *Lakes of Grass:Regenerating Bourgou in the Inner Delta of the Niger river* . Technical Publication No. 2. Spring 1990. UNSO. New York. 16 pp.

POTENTIAL BREAKTHROUGHS FOR GRAIN FARMERS (APPENDIX A)

Bruggers, R. L. and C.C.H. Elliott, eds. 1989. *Quelea quelea: Africa's Bird Pest.* Oxford University Press, Oxford. UK.

Butler, L.G., G. Ejeta. D. Hess, B. Siama, Y. Weerasuriya. and T. Cai. 1991. Some novel approaches to the *Striga* problem. Pp. 500-502 in J.K. Ransom, et al., eds., *Proceedings of the Fifth International Symposium on Parasitic Weeds.* Nairobi. Kenya. 24-30 May. 1991. Centro Internacional de Mejoramiento de Maiz y Trigo. Mexico City.

Mundy, P.J. and M.J.F. Jarvis. eds. 1989. *Africa's' Feathered Locust.* Baobab Books. Harare. Zimbabwe. 166 pp.

POTENTIAL BREAKTHROUGHS IN GRAIN HANDLING (APPENDIX B)

Shankara, R., N.G. Malleshi, H. Krishnamurthy, M.N. Narayana, and H.S.R. Desikachar. 1985. Development of mini grain mill for dehusking and grinding of cereals. *Journal of Food Science Technology* 22:91.

POTENTIAL BREAKTHROUGHS IN CONVENIENCE FOODS (APPENDIX C)

Central Food Technology Research Institute (CFTRI). 1982. *Annual Report.* Mysore. Karnataka, India.

Coetzee, W.H.K. and I.S. Perold. 1958. Pre-cooked and enriched cereal products. *South African Journal to Agricultural* Science 1:327-333.

Desikachar, H.S.R. 1977. Processing of sorghum and millets for versatile food uses in India. In D.A. V. Dendy, ed., *Proceedings of a symposium on Sorghum and Millets for Human Food. Vienna, 11-12 May, 1976*. Tropical Products Institute. London. 41 pp.

Hoseney, R.C., E.V. Marston and D.A.V. Dendy. 1981. Sorghum and millets. In Y. Pomeranz. ed., *Advances in Cereal Science and Technology, Vol IV.* AACC, St. Paul, Minnesota.

Hulse, J.H.. E.M. Laing, and O.E. Pearson. 1980. Sorghum and millets: Their composition and nutritive value. IDRC. Ottawa, Academic Press, London.

Malleshi, N.G. and H.S.R. Desikachar. 1981. Varietal differences in puffing quality of ragi (*Eleusine coracana*) *Journal of Food Science and Technology* 18(1):30-32.
Malleshi, N.G. and H.S.R. Desikachar. 1982. Formulation of a weaning food with low hot-paste viscosity based on malted ragi (*Eleusine coracana*)and green gram (*Phaseolus radiatus*). *Journal of Food Science and Technology* 19(5): 193-197.
Kumate, J. 1983. Relative Crispness and Oil Absorption Quality of *Sandige* (Extruded Dough) from Cereal Grains. M.Sc. Dissertation. University of Mysore. Mysore, India.
Malleshi, N.G. and H.S.R. Desikachar. 1986. Influence of malting conditions on quality of finger millet malt. *Journal of the Institute of Brewing* 92(1):81-83.
Malleshi. N.G. and H.S.R. Desikachar. 1986. Studies on comparative malting characteristics of some tropical cereals and millets. *Journal of the Institute of Brewing* 92(1):174-176.
Malleshi, N.G. and H.S.R. Desikachar. 1986. Nutritive value of malted millet flours. *Plant Food for Human Nutrition* 36(3): 191-196.
Perten, H. 1983. Practical experience in processing and use of millet and sorghum in Senegal and Sudan. *Cereal Foods World* 28:680-683.
Young. R., M. Haidara. L.W. Rooney. and R.D. Waniska. 1990. Parboiled sorghum: development of a novel decorticated product. *Journal of Cereal Science* 11:277-289. (Appendix C is based largely on this paper.)

POTENTIAL BREAKTHROUGHS IN CHILD NUTRITION (APPENDIX D)

Bang-Olsen, K.. B. Stilling, and L. Munck. 1987. Breeding for high-lysine barley. *Barley Genetics* 5:865-870.
Bang-Olsen, K., B. Stilling, and L. Munck. 1991. The feasibility of high-lysine barley breeding: a summary. *Barley Genetics* 6:433-438.
Evans, D.J. and J.R.N. Taylor. 1990. Extraction and assay of proteolytic activities in sorghum malt. *Journal of the Institute of Brewing* 96(4):201-207.
Horn, C.H.. J.C. Du Preez. and S.G. Kilian. 1992. Fermentation of grain sorghum starch by co-cultivation of *Schwanniomyces occidentalis* and *Saccharomyces cerevisiae. Bioresource Technology* 42(1):27-31.
Kumar, L.S., H.S. Prakash, and H.S. Shetty. 1991. Influence of seed mycoflora and harvesting conditions on milling, popping, and malting qualities of sorghum (*Sorghum bicolor*). *Journal of the Science of Food and Agriculture* 55:617-625.
Kumar, L.S., M.A. Daodu. H.S. Shetty. and N.G. Malleshi. 1992. Seed mycoflora and mailing characteristics of some sorghum cultivars. *Journal of Cereal Science* 15:203-209.
Malleshi, N.G. and H.S.R. Desikachar. 1982. Formulation of a weaning food with low hot-paste viscosity based on malted ragi (*Eleusine coracana*) and green gram (*Phaseolus radliatus*). *Journal of Food Science and Technology* 19(5):193-197.
Malleshi, N.G., M.A. Daodu, and A. Chandrasekhar. 1989. Development of weaning food formulations based on malting and roller drying of sorghum and cowpea. *International Journal of Food Science and Technology* 24:511-519.
Malleshi, N.G., H.S.R. Desikachar, and S. Venkat Rao. 1986. Protein quality evaluation of a weaning food based on malted ragi and green gram. *Plant Food for Human Nutrition* 36(3):223-230.
Munck, L. 1988. The importance of botanical research in breeding for nutritional quality characteristics in cereals. *Symbolae Botanicae Upsalienses* 28(3):69-78.
Venkatnarayana, S., V. Screenivasmurthy, and B.A. Satyanarayana. 1979. Use of ragi in brewing. *Journal of Food Science Technology* 16:204.
Venkat Rao, S., S. Kurien, D.N. Swamy, V.A. Daniel, I.A.S. Murthy, N.G. Malleshi. and H.S.R. Desikachar. 1985. Clinical trials on a weaning food of low bulk based on ragi and green gram. Paper presented at the International Workshop on Weaning Foods. Iringa, Tanzania.

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FONIO (ACHA)

Although fonio has been overlooked by most researchers, two special groups in Senegal have for some years been championing this crop's cause.

One, a program called "Fonio for the World," has been growing and distributing fonio seeds for research and development work. For information on availability of samples and terms under which they are supplied, write to Babacar N'Diaye, Conseiller Agricole chargé du Programme "Fonio pour le monde," Conseil Général de Diam-Diam, Koungheul, Senegal. The other program, concentrating on laboratory studies, is L'Institut des Sciences de l'Environnement of the Université Cheikh Anta Diop de Dakar, Boîte Postal 5005, Dakar-Fann, Senegal.

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CULTIVATED AND WILD GRAINS

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Appendix H

Note on Nutritional Charts

In the earlier chapters we have included tables of nutritional information, as well as charts that show how this information compares with that of a standard cereal such as maize or rice. They appear on the following pages.

Crop	Page
African rice	27
finger millet	44, 45
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These tables and charts should be taken only as rough indications of the lost crop's merits, not the definitive word. Some species in this book are so neglected that their nutritional components have been reported merely once or twice. It is thus probable that the figures we have used are not representative of average samples, let alone especially nutritious forms. Moreover, natural variation can occur in the nutritional content of grain from any particular species as a result of nongenetic factors such as climate and the availability of nutrients in the soil. It could be, therefore, that even better types will be discovered and developed.

The bar graphs provide what we think is a simple, but visually powerful, representation of the relative nutritional merits of two foods. With them nutritional figures between two foods (or between a food and a recommended daily allowance) can be compared almost instantly. This technique, in which the relative merits can be seen at a glance,

was devised specifically for this project, but comparable approaches could be employed equally well in Africa.*

The maize and rice values against which the African grains are compared in the bar graphs are taken from U.S. Department of Agriculture tables. The actual figures (converted to a dry-weight basis) are given below.

Component	Maize	Rice
Food energy (Kc)	408	406
Protein (g)	10.5	8.1
Carbohydrate (g)	83	90
Fat (g)	5.3	0.7
Fiber (g)	3.2	0.3
Ash (g)	1.3	0.7
Thiamin (mg)	0.43	0.08
Riboflavin (mg)	0.22	0.06
Niacin (mg)	4.1	1.8
Vitamin B6 (mg)	0.58	0.02
Folate (µg)	0.0	9.1
Pantothenic acid (mg)	0.47	1.15
Calcium (mg)	8	32
Copper (mg)	0.35	0.25
Iron (mg)	3.0	0.9
Magnesium (mg)	142	130
Manganese (mg)	0.55	1.1
Phosphorus (mg)	234	130
Potassium (mg)	320	130
Sodium (mg)	39	6
Zinc (mg)	2.5	1.2

In each of the essential-amino-acid bar graphs, the figures were compared on the basis of the amounts occurring in the protein of each grain (that is, grams per 100 grams of protein). In the other bar graphs, all nutrients were compared on a dry-weight basis so as to eliminate the distortions of different (and varying) amounts of moisture. Digestibility and other metabolic factors were not factored into the calculations. For vitamin A, the values for Retinol Equivalents were derived using standard formulas to convert literature figures given for carotenoids, ß-carotene, or International Units.

* The bar graphs were plotted electronically, so their resolution exceeds the standard error of the data (which is at minimum 10 percent). Duplicate data were discarded, and ranges were treated as separate values.

Amino Acid	Maize	Rice
Cystine	1.8	2.0
Isoleucine	3.6	4.3
Leucine	12.3	8.3
Lysine	2.8	3.6
Methionine	2.1	2.4
Phenylalanine	4.9	5.3
Threonine	3.8	3.6
Tryptophan	0.7	1.2
Tyrosine	4.1	3.3
Valine	5.1	6.1
Total	41.1	38.1

Grams per 100 g protein.

In most of the charts in the chapters we have compared the native grains in their whole-grain form with whole-grain rice and maize. A more realistic comparison might have been against polished rice and maize meal (in which the germ has been removed). This is the form in which rice and maize are normally consumed, whereas the native grains—pearl millet, fonio, finger millet, tef, and (in most cases at least) sorghum—are eaten as whole grains. Comparing nutritive values for the forms in which each is actually eaten creates an even more graphic picture of the nutritional superiority of the native grains.

Appendix I

Lost Crops of Africa Series

This is the first in a series of books highlighting the promise to be found in food plants native to Africa. The second and third volumes in the series are now being prepared for publication, and the fourth, fifth, and sixth are in the planning stage. Following are lists of the plants now being considered.

Volume 2: Cultivated Fruits

Balanites (Desert Date)	*Balanites aegyptiaca*
Baobab	*Adansonia digitata*
Butterfruit (Africado)	*Dacryodes edulis*
Carissa	*Carissa spp.,* esp. *C. macrocarpa*
Horned Melon	*Cucumis metuliferus*
Kei Apple	*Dovyalis caffra*
Marula	*Sclerocryo caffra*
Melon	*Cucumis melo*
Tamarind	*Tamcarindus indica*
Watermelon	*Citrullus lanatus*
Ziziphus	*Ziziphus mauritiana*

Volume 3: Wild Fruits

African Medlars	*Vangueria madagascariensis*
Aizen	*Boscia* spp.
Chocolate Berries	*Vitex* spp.
Custard Apples	*Annona senegalensis*
Figs	*Ficus* spp.
Gemsbok Cucumber	*Acanthosicyos naudinianus*
Gingerbread Plums	*Parinari* spp.
Grapes	*Vitis* spp.
Icacina (False Yam)	*Icacina oliviformis*
Imbe (African Mangosteen)	*Garcinia livingstonei*
Milkwoods	*Mimusops* spp.

Monkey Apple	*Anisophyllea laurina*
Monkey Orange	*Strychnos* spp.
Nara	*Acanthosicyos horrida*
Raisin Trees	*Grewia* spp.
Rubber Fruits	*Landolphia* spp.
Sour Plum	*Ximenia* spp.
Star Apples	*Chrysophyllum* spp.
Sugar Plums	*Uapaca* spp.
Sweet Detar	*Detarium senegalense*
Tree Grapes	*Lannea* spp.
Tree Strawberry	*Nauclea* spp.
Velvet Tamarind	*Dialium guineense*
Water Berry	*Syzygium guineense*
Wild Plum	*Pappea capensis*

Volume 4: Vegetables

African Eggplant	*Solanum macrocarpon*
Amaranths	*Amaranthus* spp.
Bitterleaf	*Vernonia amygdalina*
Bitter Melon	*Momordica* spp.
Baobab	*Adansonia digitata*
Bologi	*Crassocephalum biafrae*
Bungu	*Ceratotheca sesamoides*
Bur Gherkin	*Cucumis* spp.
Celosia	*Celosia* spp.
Cleome	*Cleome gynandra*
Crotalaria	*Crotalaria* spp.
Dayflowers	*Commelina* spp.
Edible Flowers	Various species
Edible Mushrooms	Various species
Edible Trees	Various species
Egusi-ito	*Cucumeropsis mannii*
Enset	*Ensete ventricosum*
Ethiopian Mustard	*Brassica carinata*
Fluted Pumpkin	*Telfairia occidentalis*
Garden Cress	*Lepidium* spp.
Gherkins	*Cucumis* spp.
Horned Melon (Kiwano)	*Cucumis metuliferus*
Jilo	*Solanum gilo*
Mock Tomato	*Solanum aethiopicum*
Okra	*Abelmoschus esculentus*
Ogunmo	*Solanum melanocerasum*

Oyster Nut	*Telfairia pedata*
Spirulina	*Spirulina* spp.
Water Leaf	*Talinum* spp.

Volume 5: Legumes

Bambara Groundnut	*Vigna subterranea*
Cowpea	*Vigna unguiculata*
Grass Pea	*Lathyrus* spp.
Guar	*Cyamopsis tetragonoloba*
Groundbean	*Macrotyloma geocarpa*
Lablab	*Lablab purpureus*
Locust Beans	*Parkia* spp.
Marama Bean	*Bauhinia esculenta*
Pigeon Pea	*Cajanus cajan*
Sword Bean	*Canavalia* spp.
Velvet Tamarind	*Dialium* spp.

Volume 6: Roots and Tubers

African Yam Bean	*Sphenostylis* spp.
Anchote	*Coccinia* spp.
Guinea Yam	*Dioscorea x cayenensis*
Potato Yam	*Dioscorea esculenta*
Other Yams	*Dioscorea* spp.
Hausa Potato	*Solenostemon rotundifolius*
Sudan Potato	*Solenostemon parviflorus*
Livingstone Potato	*Plectranthus esclentus*
Wing bean Roots	*Psophocarpus* spp.
Tiger Nut (Chufa)	*Cyperus esculentus*
Vigna Roots	*Vigna* spp., especially *V. vexillata*

We hope that this set of reports will alert everyone to the wealth of foods that are Africa's own heritage. We also hope to continue the series with volumes on nuts, oilseeds, spices, beverage plants, and others. Collectively, the resulting wealth of knowledge and guidance might well lead to a "second front" in the war on hunger in what is now the most hunger-ravaged part of the world.

We would very much like to hear from readers who would like to contribute to these future volumes. Send your name and the crop in which you're interested to:

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Above all, we'd like to appeal for photographs. Locating pictures for this book on grains has been a monumental headache; finding interesting shots for the future volumes will likely be even harder.

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The BOSTID Innovation Program

Since its inception in 1970, BOSTID has had a small project to evaluate innovations that could help the Third World. Formerly known as the Advisory Committee on Technology Innovation (ACT I), this small program has been identifying unconventional developments in science and technology that might help solve specific developing-country problems. In a sense, it acts as an "innovation scout"—providing information on options that should be tested or incorporated into activities in Africa, Asia, and Latin America.

So far, the BOSTID innovation program has published about 40 reports, covering, among other things, underexploited crops, trees, and animal resources, as well as energy production and use. Each book is produced by a committee of scientists and technologists (including both skeptics and proponents), with scores (often hundreds) of researchers contributing their knowledge and recommendations through correspondence and meetings.

These reports are aimed at providing reliable and balanced information, much of it not readily available elsewhere and some of it never before recorded. In its two decades of existence, this program has distributed more than 500,000 copies of its reports. Among other things, it has introduced to the world grossly neglected plant species such as jojoba, guayule, leucaena, mangium, amaranth, and the winged bean.

BOSTID's innovation books, although often quite detailed, are designed to be easy to read and understand. They are produced in an attractive, eye-catching format, their text and language carefully crafted to reach a readership that is uninitiated in the given field. In addition, most are illustrated in a way that helps readers deduce their message from the pictures and captions, and most have brief, carefully selected bibliographies, as well as lists of research contacts that lead readers to further information.

By and large, these books aim to catalyze actions within the Third World, but they usually also have utility in the United States, Europe, Japan, and other industrialized nations.

So far, the BOSTID innovation project on underexploited Third-World resources (Noel Vietmeyer, Director and Scientific Editor) has produced the following reports.

Ferrocement: Applications in Developing Countries (1973). 104 pp.

Mosquito Control: Perspectives for Developing Countries (1973). 76 pp.

Some Prospects for Aquatic Weed Management in Guyana (1974). 52 pp.

Roofing in Developing Countries: Research for New Technologies (1974). 84 pp.

An International Centre for Manatee Research (1974). 38 pp.

More Water for Arid Lands (1974). 165 pp.

Products from Jojoba (1975). 38 pp.

Underexploited Tropical Plants (1975). 199 pp.

The Winged Bean (1975). 51 pp.

Natural Products for Sri Lanka's Future (1975). 53 pp.

Making Aquatic Weeds Useful (1976). 183 pp.

Guayule: An Alternative Source of Natural Rubber (1977). 92 pp.

Aquatic Weed Management: Some Prospects for the Sudan (1976). 57 pp.

Ferrocement: A Versatile Construction Material (1976). 106 pp.

More Water for Arid Lands (French edition, 1977). 164 pp.

Leucaena: Promising Forage and Tree Crop for the Tropics (1977). 123 pp.

Natural Products for Trinidad and the Caribbean (1979). 50 pp.

Tropical Legumes (1979). 342 pp.

Firewood Crops: Shrub and Tree Species for Energy Production (volume 1, 1980). 249 pp.

Water Buffalo: New Prospects for an Underutilized Animal (1981). 126 pp.

Sowing Forests from the Air (1981). 71 pp.

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Amaranth: Modern Prospects for an Ancient Crop (1984). 90 pp.

Leucaena: Promising Forage and Tree Crop (Second edition, 1984). 110 pp.

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Quality-Protein Maize (1988). 112 pp.

Triticale: A Promising Addition to the World's Cereal Grains (1989). 113 pp.

Lost Crops of the Incas: Little-Known Plants of the Andes with Promise for Worldwide Cultivation (1989). 427 pp.

Microlivestock: Little-Known Small Animals with a Promising Economic Future (1991). 468 pp.

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Vetiver: A Thin Green Line Against Erosion (1993).

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Energy

33. **Alcohol Fuels: Options for Developing Countries.** 1983, 128 pp. Examines the potential for the production and utilization of alcohol fuels in developing countries. Includes information on various tropical crops and their conversion to alcohols through both traditional and novel processes. ISBN 0-309-04160-0.

36. **Producer Gas: Another Fuel for Motor Transport.** 1983, 112 pp. During World War II Europe and Asia used wood, charcoal, and coal to fuel over a million gasoline and diesel vehicles. However, the technology has since been virtually forgotten. This report reviews producer gas and its modern potential. ISBN 0-309-04161-9.

56. **The Diffusion of Biomass Energy Technologies in Developing Countries.** 1984, 120 pp. Examines economic, cultural, and political factors that affect the introduction of biomass-based energy technologies in developing countries. It includes information on the opportunities for these technologies as well as conclusions and recommendations for their application. ISBN 0-309-04253-4.

Technology Options

14. **More Water for Arid Lands: Promising Technologies and Research Opportunities.** 1974, 153 pp. Outlines little-known but promising technologies to supply and conserve water in arid areas. ISBN 0-30904151-1.

34. **Priorities in Biotechnology Research for International Development: Proceedings of a Workshop.** 1982, 261 pp. Report of a workshop

organized to examine opportunities for biotechnology research in six areas: 1) vaccines, 2) animal production, 3) monoclonal antibodies, 4) energy, 5) biological nitrogen fixation, and 6) plant cell and tissue culture. ISBN 0-309-04256-9.

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73. **Applications of Biotechnology to Traditional Fermented Foods.** 1992, 207 pp. Microbial fermentations have been used to produce or preserve foods and beverages for thousands of years. New techniques in biotechnology allow better understanding of these transformations so that safer, more nutritious products can be obtained. This report examines new developments in traditional fermented foods. ISBN 0309-04685-8.

Plants

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64. **Triticale: A Promising Addition to the World's Cereal Grains.** 1988, 105 pp. Outlines the recent transformation of triticale, a hybrid between wheat and rye, into a food crop with much potential for many marginal lands. The report discusses triticale's history, nutritional quality,

breeding, agronomy, food and feed uses, research needs, and limitations. ISBN 0-309-04263-1.

70. **Saline Agriculture: Salt-Tolerant Plants for Developing Countries.** 1989, 150 pp. The purpose of this report is to create greater awareness of salt-tolerant plants and the special needs they may fill in developing countries. Examples of the production of food, fodder, fuel, and other products are included. Salt-tolerant plants can use land and water unsuitable for conventional crops and can harness saline resources that are generally neglected or considered as impediments to, rather than opportunities for, development. ISBN 0-309-04266-6.

74. **Vetiver Grass: A Thin Green Line Against Erosion.** 1992, 000 pp. Vetiver is a little-known grass that seems to offer a practical solution for controlling soil loss. Hedges of this deeply rooted species catch and hold back sediments. The stiff foliage acts as a filter that also slows runoff and keeps moisture on site, allowing crops to thrive when neighboring ones are desiccated. In numerous tropical locations, vetiver hedges have restrained erodible soils for decades and the grass—which is pantropical—has shown little evidence of weediness. ISBN 0-309-04269-0.

77. **Lost Crops of Africa: Volume 1, Grains.** (1995) Many people predict that Africa in the near future will not be able to feed its projected population. What is being overlooked, however, is that Africa has more than 2,000 native food plants, few of which are receiving research or recognition. This book describes the potentials of finger millet, fonio, pearl millet, sorghum, tef, and other cereal grains that are native to Africa.

Innovations in Tropical Forestry

35. **Sowing Forests from the Air.** 1981, 64 pp. Describes experiences with establishing forests by sowing tree seed from aircraft. Suggests testing and development of the techniques for possible use where forest destruction now outpaces reforestation. ISBN 0-309-04257-7.

41. **Mangium and Other Fast-Growing Acacias for the Humid Tropics.** 1983, 63 pp. Highlights 10 acacia species that are native to the tropical rain forest of Australasia. That they could become valuable forestry resources elsewhere is suggested by the exceptional performance of *Acacia mangium* in Malaysia. ISBN 0-309-04165-1.

42. **Calliandra: A Versatile Small Tree for the Humid Tropics.** 1983, 56

pp. This Latin American shrub is being widely planted by villagers and government agencies in Indonesia to provide firewood, prevent erosion, provide honey, and feed livestock. ISBN 0-309-04166-X.

43. **Casuarinas: Nitrogen-Fixing Trees for Adverse Sites.** 1983, 118 pp. These robust, nitrogen-fixing, Australasian trees could become valuable resources for planting on harsh eroding land to provide fuel and other products. Eighteen species for tropical lowlands and highlands, temperate zones, and semiarid regions are highlighted. ISBN 0-309-04167-8.

52. **Leucaena: Promising Forage and Tree Crop for the Tropics.** 1984 (2^{nd} edition), 100 pp. Describes a multipurpose tree crop of potential value for much of the humid lowland tropics. Leucaena is one of the fastest growing and most useful trees for the tropics. ISBN 0-309-04250-X.

71. **Neem: A Tree for Solving Global Problems.** 1992, 151 pp. The neem tree is potentially one of the most valuable of all trees. It shows promise for pest control, reforestation, and improving human health. Safe and effective pesticides can be produced from seeds. Neem can grow in arid and humid tropics and is a fast-growing source offuelwood. ISBN 0-309-04686-6.

Managing Tropical Animal Resources

32. **The Water Buffalo: New Prospects for an Underutilized Animal.** 1981, 188 pp. The water buffalo is performing notably well in recent trials in such unexpected places as the United States, Australia, and Brazil. Report discusses the animal's promise, particularly emphasizing its potential for use outside Asia. ISBN 0-309-04159-7.

44. **Butterfly Farming in Papua New Guinea.** 1983, 36 pp. Indigenous butterflies are being reared in Papua New Guinea villages in a formal government program that both provides a cash income in remote rural areas and contributes to the conservation of wildlife and tropical forests. ISBN 0-309-04168-6.

45. **Crocodiles as a Resource for the Tropics.** 1983, 60 pp. In most parts of the tropics, crocodilian populations are being decimated, but programs in Papua New Guinea and a few other countries demonstrate that, with care, the animals can be raised for profit while protecting the wild populations. ISBN 0-309-04169-4.

46. **Little-Known Asian Animals with a Promising Economic Future.** 1983, 133 pp. Describes banteng, madura, mithan, yak, kouprey, babirusa, javan warty pig, and other obscure but possibly globally useful wild and domesticated animals that are indigenous to Asia. ISBN 0-309-04170-8.

68. **Microlivestock: Little-Known Small Animals with a Promising Economic Future.** 1990, 449 pp. Discusses the promise of small breeds and species of livestock for Third World villages. Identifies more than 40 species, including miniature breeds of cattle, sheep, goats, and pigs; eight types of poultry; rabbits; guinea pigs and other rodents; dwarf deer and antelope; iguanas; and bees. ISBN 0-309-04265-8.

Health

49. **Opportunities for the Control of Dracunculiasis.** 1983, 65 pp. Dracunculiasis is a parasitic disease that temporarily disables many people in remote, rural areas in Africa, India, and the Middle East. Contains the findings and recommendations of distinguished scientists who were brought together to discuss dracunculiasis as an international health problem. ISBN 0-309-04172-4.

55. **Manpower Needs and Career Opportunities in the Field Aspects of Vector Biology.** 1983, 53 pp. Recommends ways to develop and train the manpower necessary to ensure that experts will be available in the future to understand the complex ecological relationships of vectors with human hosts and pathogens that cause such diseases as malaria, dengue fever, filariasis, and schistosomiasis. ISBN 0-309-04252-6.

60. **U.S. Capacity to Address Tropical Infectious Diseases.** 1987, 225 pp. Addresses U.S. manpower and institutional capabilities in both the public and private sectors to address tropical infectious disease problems. ISBN 0-309-04259-3.

Resource Management

50. **Environmental Change in the West African Sahel.** 1984, 96 pp. Identifies measures to help restore critical ecological processes and thereby increase sustainable production in dryland farming, irrigated agriculture, forestry and fuelwood, and animal husbandry. Provides baseline information for the formulation of environmentally sound projects. ISBN 0-309-04173-2.

51. **Agroforestry in the West African Sahel.** 1984, 86 pp. Provides

development planners with information regarding traditional agroforestry systems—their relevance to the modern Sahel, their design, social and institutional considerations, problems encountered in the practice of agroforestry, and criteria for the selection of appropriate plant species to be used. ISBN 0-309-04174-0.

72. **Conserving Biodiversity: A Research Agenda for Development Agencies.** 1992, 127 pp. Reviews the threat of loss of biodiversity and its context within the development process and suggests an agenda for development agencies. ISBN 0-309-04683-1.

Forthcoming Books from BOSTID

Lost Crops of Africa: Volume 2, Cultivated Fruits. (1996) This report details the underexploited promise of about a dozen native African fruits. Included are such species as baobab, butter fruit, horned melon, marula, and watermelon.

Foods of the Future: Volume 1, Promising Tropical Fruits. (1996) Of the more than 3,000 edible tropical fruits, only four—banana, pineapple, mango, and papaya—are major resources. This report will describe many more that could have significance for increasing worldwide food supplies, improving nutrition, adding new flavors to world cuisine, and boosting economic advancement.

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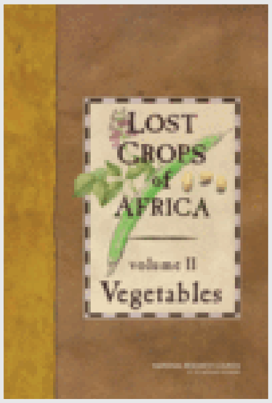

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When the idea for a project on native African food plants was first mooted, more than 1,000 people nominated their favorite grains, fruits, nuts, vegetables, legumes, and other plants. All told, over 100 species were suggested for inclusion. Indeed, the numbers and the enthusiasm were so high that we decided to produce separate volumes on grains, vegetables, and fruits. We certainly are grateful to all who helped launch the program, but the following are the ones who especially provided the technical details and insights that created the chapters of this particular book.

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PREFACE

This is the second volume in a series highlighting untapped promise to be found among Africa's traditional food plants. It has been created because within that huge mass of land below the Sahara there exist several thousand indigenous plant species, already selected for food production, that still fall outside the ambit of modern research and economic development. Some are staffs of life for thousands of communities in desperate need of help, so the lack of research attention to them is a disgrace of our times.

The food plants in question are not without merit. Humanity's oldest, they have been feeding people since the beginning. Many thrive in the harsh conditions that many Africans confront daily. And many are exceptionally nutritious. Yet none are receiving adequate scientific or institutional support, despite their significance where the needs for food, nutrition, and rural development are perhaps greater than anywhere else.

We call such neglected foods the "lost crops of Africa." And this abundance of half-forgotten edibles includes hundreds of vegetables. By highlighting a selection of these nutritious gems hidden in plain sight, we hope to stimulate Africa-wide and perhaps worldwide actions that boost their productivity and production, to the advantage of millions now existing at the mercy of fate. Although the project's ultimate aim is to raise nutritional levels, diversify agriculture, and create economic opportunities where all three are most needed, it would be wrong to conclude that Africa's vegetables lack relevance elsewhere. On the contrary, many may offer untold global potential.

It should be understood that the vegetables themselves are in some places very well known. It is mainly to scientists, policymakers, and the world at large that they remain "lost." Such outsiders include of course many in Europe, North America, and elsewhere who influence African research priorities, directly or indirectly from afar. But the outsiders also include science establishments and policymakers within African nations. In this regard it is noteworthy that many sub-Saharan countries allocate their meager agricultural research funds almost exclusively to major international crops that were introduced to Africa in the past.

The current text is designed to reach out to leaders who can direct increased consideration toward the ancestral food plants. In addition, we hope to touch technical experts and open their eyes to the importance of working on these indigenous crops. In the main, though, we hope to inspire

focus on these crops from non-governmental organizations, willing citizens, students looking for research-opportunities, and other enterprising members of the public within the 30-some countries where these vegetables are found in the ground.

In structuring the chapters and selecting the words, we've borne this broad audience in mind. This is why the text has a different feel and form from most scientific publications. Here, we're trying to penetrate an almost universal veil of ignorance by exposing the potential inherent in a collection of overlooked food plants. The information, we trust, will stimulate activities that will provide each plant a chance to achieve the promise still awaiting elaboration in its genes and in the germplasm occupying prime space across Africa.

This book's beginnings go back to a questionnaire that asked Africans and Africa specialists to identify indigenous food plants with unrealized potential. The response was overwhelming; a thousand respondents replied, naming more than 300 personal favorites. Among the nominations were more than 50 vegetables deemed to have unrealized promise of a significant character. From those we chose the 18 highlighted here.[1]

Each description of the selected species begins with an overview aimed at capturing the attention of policymakers, philanthropists, planters, and others having a general interest. The text then proceeds with increasing levels of detail and technical content, aimed at stimulating professional interest among nutritionists, horticulturists, geneticists, and others trained in the various specialties capable of moving the plants solidly into the mainstream of modern endeavor.

These descriptions were initially compiled from literature, queries by mail (and, more recently, email), electronic sources, telephone conversations, and experience gathered through years of dealing with little-known tropical crops. Next we emailed drafts (accompanied by a request for editorial input) to several hundred researchers, most of whom had experience in Africa and more than half of whom were actually there. The response was passionate, and once the new wealth of contributions was incorporated, each redrafted chapter was forwarded to a handful of people (or in some cases many more) who by then we'd learned knew special aspects of that particular plant such as its cultivation, nutritional content, usages, or other relevant information.

With these appraisals in hand, each chapter was yet again reworked to incorporate this round of improvements, including many points not in the prior literature. Following repeated entreaties for clarification of specific points and many rewrites and additional reviews, the results became the crop descriptions making up the body of this volume. While there is no way to

[1] The final selection was to some extent arbitrary—based as much upon available information as on strict scientific assessment. The species set aside could and should fill additional volumes.

achieve full accuracy dealing with such little-known plants, we believe the presentations are balanced and informative.

The book's introductory statements were then composed, based largely on wisdom mined from the reviewers' insights. The combined result was evaluated by a National Research Council panel with deep experience in Africa's agriculture and food problems (see list above). These individuals assessed the relative balance of the manuscript and, in broad terms, evaluated the overall inherent potential of indigenous African vegetables as detailed in the Introduction. The final draft was then reviewed in accordance with procedures approved by the National Academies' Report Review Committee (see below).

These exhaustive processes led to the present volume. It is important to understand that this is neither a textbook nor a technical survey of African botany or agriculture. The writing puts it somewhere between a strictly scientific account and a popular review. As mentioned, we've crafted the message to interest not just specialists but also administrators, entrepreneurs, and researchers unaware of these particular vegetables or their promise.

As already indicated, this is the second in a series. The preceding volume described notable cereal grains found amidst the vast plains, savannas, and deserts below the Sahara. Published in 1996, it covered:

- African Rice (*Oryza glabberima*)
- Finger Millet (*Eleusine coracana*)
- Fonio (*Digitaria exilis* and *D. iburua*)
- Pearl Millet (*Pennisetum* spp.)
- Sorghum (*Sorghum glaucum*)
- Tef (*Eragrostis tef*)
- Other cultivated grains (*Brachiaria*, *Triticum*, *Paspalum*, etc.)
- Wild grains (*Echinochloa*, *Paspalum*, etc.).

A third book accompanies this one. Volume III focuses on African fruits. Its first half highlights 10 cultivated delights:

- Balanites (*Balanites aegyptiaca*)
- Baobab (*Adansonia digitata*)
- Butterfruit (*Dacryodes edulis*)
- Carissa (*Carissa* species)
- Horned Melon (*Cucumis metaliferus*)
- Kei Apple (*Dovyalis caffra*)
- Marula (*Sclerocarya birrea*)
- Melon (*Cucumis melo*)
- Tamarind (*Tamarindus indica*)
- Watermelon (*Citrullus lanatus*)

The second half covers 14 wild fruits:

- Aizen (*Boscia* species)
- Chocolate Berries (*Vitex* species)
- Custard Apples (*Annona* species)
- Ebony (*Diospyros* species)
- Gingerbread Plums (*Parinari* and kindred genera)
- Gumvines (*Landolphia* and *Saba* species)
- Icacina (*Icacina* species)
- Imbe (*Garcinia livingstonii*)
- Medlars (*Vangueria* species)
- Monkey Oranges (*Strychnos* species)
- Star Apples (*Chrysophyllum* and related genera)
- Sugarplums (*Uapaca* species)
- Sweet Detar (*Detarium senegalense*)
- Tree Grapes (*Lannea* species)

The Introduction is laid out so that readers can quickly zero in on plants that may be particularly useful to them. The overall qualities of each vegetable are outlined in brief paragraphs. These are followed by discussions on overcoming malnutrition, boosting food security, fostering rural development, and sustainable landcare, highlighting the potential contribution of each individual species to these development goals. Their overall promise is ranked in a single table (see Table 1) that also shows their general location in Africa.

In the present volume we have abandoned our longstanding habit of appending such things as addresses of research contacts, sources of seed, and technical papers that provide more detail. These days, the Internet is the best place to find such information, which advances too rapidly for print to keep pace. Further, much of the literature on these plants is obscure and of little help to those trying to advance these species; not only does a static list quickly go stale, but much time could be wasted acquiring these sources only to find the same information in a matter of minutes on-line. Our experience is also that printed contact lists quickly become obsolete, misdirecting communications to those who have moved and burdening those no longer engaged, while not representing those newly involved. Circumspection for personal information also pertains to acquiring germplasm, which should only be requested through appropriate channels due to the world's heightened phytosanitary, cultural, and legal concerns.

Although Internet communication is far from satisfactory in much of Africa, advancement during the course of this study has already been astounding, and the ability of those even in the most difficult circumstances

to efficiently access information is impressive. The future of these plants is in collaborative networks of interested workers in Africa and elsewhere freely sharing information and experiences.[2] For such ends, the dynamic possibilities offered by electronically organizing, parsing, and presenting information provide much greater flexibility than the fixed text of the printed page. Much core information on vegetables discussed in this volume is rapidly, or already, appearing online. This new arena allows all to participate and all to benefit.

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This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Academies' Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the process.

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[2] An example of such collaboration is embodied by a network undertaken by the International Plant Genetic Resources Institute (IPGRI): Guarino, L., ed. 1997. *Traditional African Vegetables. Promoting the conservation and use of underutilized and neglected crops*. 16. Proceedings of the IPGRI International Workshop on Genetic Resources of Traditional Vegetables in Africa: Conservation and Use, August 29-31, 1995, ICRAF-HQ, Nairobi. Institute of Plant Genetics and Crop Plant Research, Gatersleben/IPGRI, Rome (online via ipgri.cgiar.org/publications). On a broader scale, prota.org (Plant Resources of Tropical Africa), a joint African/European nonprofit foundation, intends to eventually document 7000 species useful in Africa (both indigenous and introduced), while other Internet sites dealing with these plants, such as ecoport.org, are driven through user input and reciprocal sharing of knowledge.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Calvin O. Qualset, University of California, Davis. Appointed by the National Academies, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authors and the institution.

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A NOTE ON TERMS

Throughout this book the word "Africa" always refers to "Africa south of the Sahara."

The plants, too, are sub-Saharan. North African species, being biogenetically part of the Mediterranean-Near East complex, were generally ignored.

We refer to the vegetables by common names rather than scientific ones. This simplifies communication in a book written more for generalists than for specialists.

We have preferred to use English common names where possible, except where they imply that a plant pertains only to one locale or ethnic group (e.g., Hausa potato). An exception is Bambara bean, known as such across the continent. In other cases, however, we have not hesitated to suggest uncommon but more alluring names. A harsh sounding or off-putting name can be a body blow to the advancement of an otherwise excellent vegetable.

The local-name lists that appear in the chapters are not by any means exhaustive. They are included only as a rough help in pinpointing the plant being described.

Unless noted otherwise, nutritional values given are presented on a dry-weight basis to eliminate moisture differences between samples. We depend on reported values, many of which are old or incomplete or otherwise questionable, and which may never have been independently verified. Each species deserves modern verification.

We frequently refer to vitamin A or equivalents—notably when discussing the nutrition of each vegetable. It should be understood, however, that vitamin A is formed in our bodies. Within the plant, it occurs as provitamin A carotenoids. Modern protocols for measuring the levels have rarely been applied to these plants.

Because this book will be employed in regions beyond Africa, we have in most cases used internationally recognizable names when referring to non-African crops. Examples include peanut for groundnut, papaya for pawpaw and cassava rather than its more common African name, manioc.

A WORD TO READERS

Everyone who works with plants assumes responsibilities. Some species described in this report—especially those which are less than domesticated—may be pestiferous or invasive outside their natural environs, and thus require due caution and on-going scientific assessment after introduction. Unless professionally inspected, they may also carry along unseen pests and diseases (particularly small insects and microbes such as virus or bacteria) whose populations might explode catastrophically in new locations. In addition, plant genes and germplasm are subject worldwide to both tangible- and intellectual-property laws; these legal rights hold especially true for food plants in which others—whether farmers or financiers—have already invested thought and labor or capital. For these reasons, most nations have official protocols based on intergovernmental conventions governing the safe and legitimate transfer of plant materials. These protect both people and the environment, and are rarely any obstacle to helpful activities. In the best interest of all parties, it is crucial that the requirements of such protocols be strictly followed.

FOREWORD

The great thing about the edibles highlighted here is that they can be used for probing the heart of Africa's most basic problems—hunger, malnutrition, rural poverty, environmental destruction. Collectively, they have the power to pump rich new nutrition into what is now an anemic food supply, sputtering rural economy, uncertain public health, and less-than sustainable farm operations.

Some people argue that these problems are but symptoms arising from deeper evils associated with low levels of economic productivity. Yet on that score too, edibles highlighted in the following pages can help. In theory at least, they can expand opportunities and contribute to the resuscitation of prosperity across rural Africa—locales where human life has in recent decades suffered hardest.

Another thing, no less great, is the fact that these vegetables offer ways by which people throughout the continent can work together for a common good. Fundamental, too, is cooperation between those who know tradition and those who know technology. Non-Governmental Organizations might make all the difference in building those bridges. The NGO proliferation is a change from the past, and for the development of the indigenous vegetables such organizations seem ideally poised to straddle voids between science and society, the past and the future, Francophone and Anglophone locales, and technologists the world around. At various levels, small active groups could coordinate, sponsor, manage, direct, or monitor the collection of plant materials, the documentation of traditions, the experimentation within laboratories, and so forth—all in relation to a vegetable of particular merit for the people and the environment they are dedicated to serve.

Indeed, individuals on more fortunate continents can also reach in and help improve the lives of Africans through the advancement of such promising resources as we describe. That notion may seem strange, but in furthering these particular food plants there's scope for almost everyone—regardless of their level of influence, sphere of interest, or place on earth. This is not a novel notion: everywhere else, crops were developed both by outside influences *and* by local actions.

Of course experts in the relevant sciences can make vital advances in getting Africa back to its roots. In furthering any of these crops there's a place for food technology, nutritional analysis, DNA probes, taxonomic identification, toxicological tests, agronomy, horticulture, pathology, vegetative propagation, selection, breeding, and more.

Specialists in such subjects could make a big difference in boosting the better use of native foodstuffs in a continent woefully deficient in such expertise. Every chapter elaborates technical tasks needing attention. And

with today's communications individuals on one side of the world don't have to leave home to champion a crop on the other. Electronic collaborations are increasingly common, and Africa's under-exploited foods seem ideal vehicles for the world's specialists to interact at many levels and in many ways with the world's neediest farmers and lift their meager lives.

Beyond specialized scientific inputs, there's much scope for ordinary folks to figure in the revitalization of rural Africa. Examples include:

- Creating classroom materials and conducting children's gardening projects;
- Learning from local farmers how to master the complexities of growing each vegetable under the prevailing local conditions;
- Reaching out to professionals in subjects such as food technology, nutrition, and horticulture to alert them to African vegetables' needs;
- Setting up websites (which might, for instance, highlight a vegetable or a region's indigenous vegetables or perhaps the use of native produce to counter a problem such as malnutrition);
- Fostering traditional vegetables in university courses, government extension, agricultural fairs, and operations run by foundations, foreign governments, development banks, and the rest;
- Coordinating the collection of a lost crop's seeds, locally, nationally, regionally, or perhaps internationally;
- Translating documents such as this one into local languages or translating scientific papers to-and-from especially French;
- Compiling country profiles of a lost crop, including regional recipes, beliefs, stories, management methods;
- Running an email alert service to pass on the latest news relating to these resources as advances emerge worldwide;
- Developing and adapting processing, storage, and transportation technologies;
- Organizing web-links among institutions and individuals working on Africa's "lost crops"
- Establishing a cyber-exchange linking suppliers of African crop products to marketplaces around the world;
- Developing new recipes incorporating them into different cuisines;
- Searching colonial-era archives (those housed locally as well as others in Europe) for any previous investigations;

- Recording these crops' myriad vernacular names and uses; or
- Providing a forum for swapping or selling seeds or other planting materials in an open, ethical exchange.

As we've said, we hope our words will stimulate such actions and lead to a wider, wiser, older, newer, and sounder sub-Saharan food supply. We think that, with commitment, the rewards to any reader stimulated into action could be legion. Involvement with any of these vegetables can touch the hearts of the humans most needing a hand up. For Africa, these species represent some of the best foods for the future. They also represent some of the best science projects. Although generally ignored by researchers, many of these crops are quite familiar in farms, gardens, markets and, in some cases, thousands of square kilometers of hillsides and savannas. Most are suited to the small plots, mixed cultivation, poor soils, local diets, and time-honored lifestyles of family or village. To have survived into modern times without "official" intellectual support indicates something about their inner strengths.

Taken all round, then, these lost crops constitute an obvious, though not necessarily simple, way by which Africa can reach back to the past and help fashion *for itself* a future.

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INTRODUCTION

It might be supposed that a hungry continent would exploit all its available food plants to the fullest, but in Africa's case that is not so. The region below the Sahara is home to hundreds of contributors to the food supply, almost none of which is currently accorded scientific support, official promotion, or inclusion in development schemes.

In the beginning, Africa's edibles fed humanity. The earliest emigrants out of Africa—long before agriculture—found new foods on their journeys, but at home there was a contraction of agrodiversity as farming increasingly focused attention on those plants most practical as mass-suppliers of food in the greatest number of places. Still and all, for many thousands of years, hundreds of wild and (in time) cultivated native species complemented each other to comprise the core of the continental food supply.

Then before recorded history, a pivotal plant migration began as a few Asian foods wended westward to become new links in the African food chain (sorghum and others took the return route from Africa). They arrived partly thanks to increasing trade between India and Africa's eastern seaboard, as well as overland and perhaps even through surprising long-distance connections between Madagascar and today's Indonesia. Exotic species from Asia—most notably rice, bananas (in their various forms), and sugarcane—began contributing more and more to life below the Sahara.

Yet many Africans remained largely dependent on traditional food plants until about five centuries ago, when adventurers and slavers sailing the western seaboard introduced a collection of American crops. These additions notably included maize (corn), cassava (manioc), peanut (groundnut), sweet potato, tomato, common bean, chili peppers, and pumpkin. As is common with nonnative plants, the new arrivals tended toward robust and productive growth, and subsequent centuries saw them spread across Africa as farmers integrated these helpful adjuncts into their age-old livelihood strategies. That inevitably meant that more of the traditional contributors fell away from the food supply and the minimization process proceeded.

During the colonial era the process of discarding indigenous crops gained further momentum, as the official focus shifted to those familiar crops of mercantile interest, such as cane, chocolate, coffee, cotton, and other durable, transportable, and valuable crops of that sort. Indeed, during those times subsistence crops were almost entirely neglected in organized agriculture, while valuable exportable cash crops were cultured, harvested, graded, and protected against rodents, insects, and decay with exceptional

efficiency and dispatch. And an end result of these historical trends was that most of Africa's food these days comes from a mere 20 or so species, almost all of foreign extraction.

Like grains and fruits, Africa's ancient vegetables were vulnerable to the sweep of these events. Long ago, hundreds of leaves, roots, tubers, corms, rhizomes, bulbs, seeds, buds, shoots, stems, pods, or flowers were eaten. Yet across Africa today the main vegetables are crops such as sweet potato, cooking banana (plantain), cassava, peanut, common bean, peppers, eggplant, and cucumber. Countries in the elevated central regions—Burundi, Rwanda, Ethiopia, and Kenya—grow potato. Banana dominates Rwanda, and Ethiopia also relies on chickpea and lentil. And South Africa records its leading vegetable crops as potato, tomato, green mealies (maize), sweet corn, onion, pumpkin, carrot, cabbage, lettuce, and beetroot.

The disconnect in such modern-day enumerations is that these "African" vegetables come from Asia or the Americas. Indeed, a popular textbook on vegetables in Africa features about 100 species, only 3 of which are native born. Out of the continent's top vegetables today, only cowpea, yam, and okra are African.

This situation is not, in itself, a major detriment. The United States, after all, has almost half of sub-Saharan Africa's population and eats essentially no local food plants whatsoever.[1] But unlike the United States, Africa needs more and better food. And unlike America, which is biologically deprived of native food plant abundance, Africa also has the blessing of hundreds of worthy candidates waiting in the wings—the old ones that during the course of history got dropped from the food supply not through insufficient merit but through the negligence or priorities of eras now past and for reasons no longer relevant.

There are lessons to be learned from such history. Many foods of the utmost importance today were bypassed in the past because they were considered "poor people's plants." Peanuts, potatoes, and many other top-line crops once suffered this discrimination. In the United States the peanut was scorned as "merely slave food" until little over a century ago, and in the 1600s the English refused to eat potato on the basis that it was "Irish food." The list is lengthy, and cultural bias against peasant crops is an ultimate calamity because plants that poor people grow are usually robust, productive, self-reliant, and useful—the very type well-suited to feeding the hungriest and most vulnerable sections of society.

Surely the door is now open to a renaissance of Africa's vegetable resources. Sadly, though, even in our times, such historical exclusionary trends continue. The imbalance between the traditional and the introduced species, already worrisome, continues tipping toward an even greater

[1] The only food crops native within the U.S. borders are minor contributors, such as sunflower, Jerusalem artichoke, Concord grape, pecan, cranberry, and small fruits like blueberry and raspberry.

reliance on other people's plants. More correctly, it is tipping against the use of, and appreciation for, the traditional vegetables that have fed Africans for tens of thousands of years. While science makes the top resources better, the lesser ones fall farther behind, shunting the vast majority of the cuisine into anonymity, if not extinction. This means most of Africa's own edibles have yet to receive due attention, let alone a chance to develop to their potential under the power and promise inherent in modern capabilities.

The global homogenization of lifestyles is not fully to blame for squeezing out traditional vegetables, for modern connections and wealth have also led to an explosion in the availability of novel foods in every developed market. Rather, to a considerable extent this neglect seems to be an unintended consequence of agricultural successes in research-rich regions. And not unnaturally, Americans, Europeans, Asians, and others see Africa's future in the vegetables they themselves depend upon. Thus soybean and the rest garner the research spotlight, rise to ever-greater levels of food and cash generation, and seem thereby to justify even more research support.

Something of this scientific spiral can be deduced from the amount of research now dedicated to soybean. By comparison, Africa's yam and okra can hardly be said to get any support at all; even cowpea, probably the best-funded of all African vegetables, falls far short of a soybean standard. Indeed, it is no coincidence that the continent's top three traditional vegetable resources basically languish while their foreign counterparts seize ever more momentum within the lands to which cowpea, yam, and okra have contributed with distinction for millennia. And beyond those three "visible" African vegetables lies a huge array of "invisibles," whose names remain unknown in the world's leading vegetable research institutions and which as a consequence get left without support. An irony that demonstrates the potential for such "lost" African crops is that soybean itself was little-known outside Asia a century ago, yet within a lifetime it has become a crop of global heft.

Emphatically, to the extent soybean can benefit Africa, research support is a very good thing. Competition is as healthy in crops as it is in commerce, and there will always be losers. However, to feed a continent as vast and diverse as this requires more and better adapted food crops. That in turn points to the age-old vegetables, feeding people long before Africans discovered Asia, Europe, and America; these "lost crops" should be included among Africa's future options.

When compared with the ancient stock of modern crops, these traditional African food crops remaining outside the fold of science have not been rejected because of any inherent inferiority. It is time to open minds to the power and promise of this indigenous edible wealth. It is not that the ancestors' vegetables should be placed in the forefront of efforts to feed Africa, but they deserve to be pulled out of anonymity and given a fair

chance to expose their worth to modern times. Many have important contributions to make today, and eventually—if merited—they may move on a path leading toward a well-fed continent.

Now is the opportunity to explore Africa's future in the promise of its edible botanical wealth. These days researchers are enthusiastic about genetic engineering and the new products to arise from it. This emerging technology offers promise for Africa, but enthusiasm must not obscure the fact that huge numbers of nature's organisms—already selected and improved by humans—have yet to be explored by the "traditional" scientific methods that have proven nearly miraculous at improving global food production for decades on end. Some little-known local plants may have a genetic makeup so outstanding that they could help solve some of Africa's–not to mention the world's–most pressing food problems.

Beyond all that, a revitalized development of Africa's own food plants could open new windows of opportunity beyond those agriculturists normally imagine. In principle, these domesticates can help not only feed an increasing population, but also make marginal lands more productive, lift rural incomes, and re-clothe denuded and desolate areas. Moreover, they can widen the continent's agricultural resource base, fashioning a food supply that is not only more stable but more secure. The genes for fighting off the ravages of pests and diseases may already be available. Indeed, this endeavor seems ideally suited as a mission for Africa's own under-utilized agricultural science.

But with which native vegetables should the revitalization process start? Even within living memory Africans still ate an astonishing number of different plant products. One writer lists 83 species used as vegetables just in what is today Zimbabwe. In one small part of South Africa more than 120 species were until recently common vegetables. Large 19th and 20th Century tomes (targeted largely toward scholars) were written in both English and French detailing hundreds of plants consumed daily in West Africa. Even in the arid areas of Namibia and Botswana, where environmental extremes limit options, one observer lists 18 vegetable-like plants eaten by traditional cultures in the blistering heart of the Kalihari.

It is conceivable that 3,000 native African roots, stems, tubers, leaves and leafstalks, bulbs, immature-inflorescences, and fruit-vegetables were eaten routinely. But knowledge of what can and cannot be eaten was generally passed through generations from mother to daughter and from child to child. This direct, personal, on-the-scene tutoring was effective, but taking advantage of it today is fraught with difficulty. Though some of the knowledge has been recorded, sadly much of that experience has faded from the collective memory. Merely knowing that a species was eaten is not as helpful as might be supposed, and nowadays it may be difficult to glean from the overall genepool those especially palatable specimens that were the only ones used in the past.

Yet not all is lost. Many indigenous edibles are still widely cherished across Africa today. Some are even attracting resurgent research interest. A few ground-breaking growers and creative researchers have become intrigued by these ancient resources. Indeed, plant champions Africa-wide consider that—given attention—these ancestral foods have a capacity to take their place alongside the modern marvels dominating today's textbooks, scientific treatises, and the international image of what a first-class vegetable should be.

Besides offering an important opportunity to diversify the food base, the traditional crops lend themselves to local initiative, not to mention local sentiment. Africa's own researchers and growers could lead the charge to reinvigorate these ancient resources. It is also noteworthy that advances in plant breeding, genetics, and increasingly genomics will transform these ancient and neglected resources far faster than might seem likely based on historical precedent. Generally, it is no longer necessary to invest centuries to bring a crop to its potential. Given even a little attention and support, Africa's fruits and vegetables could quickly contribute even more to the environments, nutrition, economies, and personal income–particularly women's income–of many if not most African nations.

This then is a good time to be peering past the current commercial crops and developing a complementary set of contenders. That is already happening in "post-industrial" nations, where markets abound with a cornucopia of vegetables not seen twenty years ago. For Africa, its own "lost" species are an obvious place to begin that same sensible process of diversification to meet the needs of today and beyond.

SUMMARIES OF INDIVIDUAL SPECIES

Following are summaries of the vegetables selected for treatment in this volume. Seen in overall perspective, these native resources could provide much more than food. They promise to lift the quality of life throughout the continent that needs it most. Their individual possibilities to address pressing problems of nutrition, food security, rural development, and the enviroment in Africa are focused upon in Table 1 and the sections following the 18 summaries below. Please note that the information in these summaries can also be found in the individual species chapters as well.

1. Amaranth

Vegetable amaranths (*Amaranthus* species, Amaranthaceae) are arguably the most widely eaten boiled greens throughout Africa's humid lowlands. During the production season they reportedly provide some societies with as much as a quarter of the daily protein intake. The tender young seedlings are pulled up by the roots and sold in town markets by the thousands of tons annually. In addition, the leaves and stems from full-grown plants make boiled vegetables with soft texture and mild flavor. All this has come about despite an almost total lack of formal development or official support. Given professional attention, these fast-growing vegetables could contribute even more vitally to nutrition, food security, and rural prosperity—especially the prosperity of rural women, who are the major producers.
Climate Humid lowlands, dry savannas, uplands.

2. Bambara Bean

Seeds of this legume (*Vigna subterranea*, Leguminosae) are dug from the ground like peanuts. Typically, they are then boiled, roasted, or fried, ground into flour, and blended into many traditional dishes. Despite an almost total scientific neglect, nothing fundamental appears to be stopping this especially appetizing crop from much greater contributions to the diet of much of Africa. It produces a food of exceptional nutritional quality, so a little goes a long way toward building and maintaining a solid foundation of good health. All in all, this tasty protein-rich bean promises to benefit the people most in need and hardest to reach through conventional development programs.
Climate Humid lowlands, dry savannas, uplands.

3. Baobab

The leaf of the much beloved baobab (*Adansonia digitata*, Bombacaceae) is a staple of the savanna lands below the Sahara. In an area stretching across half the continent this vegetable ranks among the commonest foods.

Bursting into foliage a little before the rains begin, the stately trees remain green and edible until a little after the rains have ceased months later. The leaf is sometimes steamed and eaten as a side-dish like spinach, but most goes straight into soups, stews, sauces, relishes, and condiments that complete the main dish of the day.

Climate Mainly dry savannas.

4. Celosia

The prettiest of all vegetable crops, celosia (*Celosia argentea*, Amaranthaceae) is used as an ornamental almost everywhere on earth. But few of its millions of admirers know that it is a common item of diet in parts of tropical Africa. The fresh young leaves, young stems, and young flower spikes are used to produce a tasty and nutritious "soup" that is a daily fare especially in West Africa. Productive and simple to grow, the plant could in the future become a much greater contributor to African welfare, especially in the hot and poorly nourished regions of the equatorial zone.

Climate Humid lowlands, uplands.

5. Cowpea

Although globally obscure, cowpea (*Vigna unguiculata*, Leguminosae) is grown by tens of millions of smallholders in Africa. West Africans alone plant an estimated 6 million hectares annually. In fact, it is estimated that 200 million children, women, and men live off the plant—consuming the seeds daily whenever available. Widely appreciated by the poor, cowpea seed is not only rich in protein but in digestible carbohydrate too. Although not strictly a "lost crop" (it traveled long-ago to South Asia, where it expanded into an important asset), it still falls far short of its potential. Indeed, that potential could be very high because this species seems strong enough to lift Africa's overall food quality.

Climate Primarily dry savannas and uplands.

6. Dika

Throughout a giant triangle from Senegal to Uganda to Angola, dika (*Irvingia wombolu* and *Irvingia gabonensis*, Irvingiaceae) is a part of the daily diet. Although this tree's fruits are popular in some areas, the seed is the major resource. These so-called "dika nuts," which are something like cashews, can be eaten raw or roasted. Most, though, are ground and combined with spices to form the key ingredient in "ogbono soup," a spicy dish extremely popular among West and Central Africans. As a result, this so-far-undomesticated tree scores high on the list of species inhabitants hope to see developed.

Climate Humid lowlands, dry savannas, uplands.

7. Eggplant (Garden Egg)

This vegetable (*Solanum aethiopicum*, Solanaceae), like its better-known Asian cousin (*S. melongena*),. provides brightly colored egg-shaped fruits that are a significant vegetable resource almost Africawide. The species is high yielding, easy to grow, and simple to harvest and handle. It is integral to many cuisines, cultures, and economies. Yet in many parts of Africa there is considerable scope for producing much better varieties in much better quantities.

Climate Humid lowlands, dry savannas, uplands.

8 Egusi

Egusi is a melon-like crop grown for its large white seeds, which in West Africa are a component of many meals. The plants themselves are from several species and genera, notably including watermelon itself (*Citrullus lanatus*, Cucurbitaceae). Ground up coarsely, the seeds thicken stews and contribute to a widely enjoyed steamed dumpling. Some are soaked, fermented, boiled, and wrapped in leaves to form a popular seasoning. They are also roasted and made into a spread not unlike peanut butter. They are even compacted into patties that serve as a meat substitute. Seen in overall perspective, this is a versatile crop with valuable for both subsistence survival and modern commerce.

Climate Humid lowlands.

9. Enset

Although few outsiders have ever heard of it, this tree-like herb (*Ensete ventricosum*, Musaceae) underpins the food supply in Ethiopia's densely populated highlands. An estimated 10 million people consume it. The plant is perhaps the biggest vegetable of all and looks like a banana "tree." The food, however, comes mainly from the trunk, which on the largest specimens can be a meter in diameter and three meters tall and is filled with starchy pith. A second food comes from underground, where can be found a corm that may be almost a meter long and a meter in diameter and is packed, like some giant potato, with starch. Any plant producing food by the cubic meter is surely something to use more intensively in a hungry continent, but so far this one is barely known to science, let alone to Ethiopia's neighbors.

Climate Upland.

10. Lablab

In Asia lablab (*Lablab purpureus*, Leguminosae) is a popular foodstuff. For the rural peoples of southern India, for instance, its pods and seeds supply much of the daily protein. The strange thing is that lablab is African. Stranger still is the fact that it is almost unknown in present-day Africa. Yet

this clambering bean possesses qualities that could prove exceptionally valuable for nutritional well-being, rural development, and environmental stability in almost every corner of its continent of origin.

Climate Humid lowlands, dry savannas, uplands.

11. Locust Bean

Another legume, the West African locust bean (*Parkia biglobosa*, Leguminosae), grows more than 20 meters tall. Its pods, which dangle all over the tree's spreading crown, contain seeds as well as a dryish pulp that can be half sugar. The seeds are gathered by the thousands of tons and peddled by itinerant traders throughout West Africa, often as a medicinal. Chiefly, they are fermented into the famous dawadawa. This sticky, sour, cheesy solid is rich in protein, vitamins, and food energy and even in the tropical heat it keeps well without refrigeration. Dawadawa is exceptionally popular as a seasoning, but it is also an important soup ingredient. This single species, which has received almost no horticultural recognition, combines likely answers to Africa's twin needs of food and tree cover.

Climate Dry savannas.

12. Long Bean

This delightful legume (*Vigna unguiculata*, Leguminosae) resembles a snap bean except for the singular fact that it is pencil-thin and up to a meter long. Often called yardlong bean in English, its green to pale-green pods are tender, stringless, succulent, and sweet. The surprising thing about what is universally acclaimed an "Oriental vegetable" is that it is a special form of cowpea—a species of unquestioned African origin (see cowpea, above). Now is the time to welcome long bean back home to contribute as much to Africa as to Asia.

Climate Humid lowlands, dry savannas, uplands.

13. Marama

Above ground, this plant (*Tylosema esculentum*, Leguminosae) produces seeds rivaling peanut and soybean in nutritive quality. Below ground, it produces a high-protein tuber much bigger even than sugar beet and much more nutritious even than potato or yam. The plant thrives in poor-quality soil and under the harshest of climates. Indeed, in its native habitat, the deserts of southern Africa, rain often stays away for years on end. But this seems a resource more in theory than reality; it is undomesticated and has far to go before anyone can truly capitalize on such valuable qualities.

Climate Semiarid lands.

14. Moringa

Yielding protein, oil, and carbohydrates, and with a lode of vitamins and minerals, moringa (*Moringa oleifera*, Moringaceae) is possibly the planet's most valuable undeveloped tree, at least in humanitarian terms. A sort of food market on a stalk, it yields at least four different edibles: pods, leaves, seeds, roots. And beyond edibles, it provides products that make village life more self-sufficient: lubricating oil, lamp oil, wood, paper, liquid fuel, skin treatments, the means to purify water, and more. The green pods, which look like giant green beans but taste something like asparagus, are notably nutritious. Foliage is an important food product as well. People in various countries boil up the tiny leaflets and eat them like spinach. Taken all round, this supreme poor-person's plant shows a remarkable capacity to help solve problems such as hunger, malnutrition, rural poverty, disease, deforestation, and visual blight. Although the experiences come almost exclusively from India, the genus *Moringa* is inherently African, so it has ancestral roots in the sub-Sahara soil.

Climate Humid lowlands, dry savannas, uplands.

15. Native Potatoes

Africa's native "potatoes" (especially *Solenostemon rotundifolius* and *Plectranthus esculentus*, Labiatae) are actually members of the Mint Family. Smaller than modern commercial potatoes, their tubers hang in bunches from the base of the plant. They are mostly boiled, but can also be roasted, baked, or fried. Despite kinship to pungent herbs like basil, mint, sage, and thyme, the tubers have a bland taste and can replace potato in most recipes—including potato salad. Not only are they nutritious, they are productive. Even in their current fairly unimproved form, native potatoes can produce a lot of food from a small area. And they seem primed for rapid advancement to a major African resource.

Climate Humid lowlands, dry savannas.

16. Okra

A perfect villager's vegetable, okra (*Abelmoschus esculentus*, Malvaceae) is robust, productive, fast growing, high yielding, and seldom felled by pests and diseases. It adapts to difficult conditions and can thrive where other food plants prove unreliable. Among its useful food products are pods, leaves, and seeds. Among its useful non-food products are mucilage, industrial fiber, and medicinals. Seen in overall perspective, this often-derided resource could be a tool for improving many facets of rural life. Its production and maintenance is fairly well known in the U.S. and elsewhere, and this offers the possibility of rapid advancement within Africa.

Climate Humid lowlands, dry savannas, uplands.

17. Shea

Although few outsiders know this tree, shea (*Vitellaria paradoxa*, Sapotaceae) remains among West Africa's most extensive food sources. West Africans employ its smooth-skinned, egg-shaped nut much like Westerners employ lard and butter. For a vegetable lipid this one is strange in that it remains solid even under tropical conditions. Countless Africans also use it for skincare, and these days shea butter is going global and going upscale as an ingredient in some of the most expensive cosmetics ever formulated.

Climate Dry savannas.

18. Yambean

The African yambean (*Sphenostylis stenocarpa*, Leguminosae) is a legume grown mainly for its fleshy swollen roots, which look something like sweet potatoes but are succulent, sweet, and crisp as a fresh-picked apple. In nutritional terms, they are a class above the mainline root crops, containing more than twice the protein of sweet potatoes, yams, or potatoes and more than ten times that of cassava. Moreover, the protein is of exceptional nutritional quality, superbly complementing the proteins of maize, sorghum, and the other staples. In addition, both seeds and leaves are edible. And the African yambean is no slouch in the yield department, either. It produces its edibles in abundance, and seems capable of delivering record quantities of protein from soils normally considered marginal.

Climate Humid lowlands and uplands.

TABLE 1: POTENTIAL ROLES FOR SELECTED AFRICAN VEGETABLES

*** = ***Outstanding;*** ** = ***Notable;*** * = ***Average***	Overall	Nutrition	Food Security	Rural Development	Sustainable Landcare	PRIMARY OCCURRENCE West Africa	Central Africa	East Africa	Southern Africa
Amaranth	**	***	**	***	*	√	√	√	√
Bambara Bean	***	***	***	***	**	√	√	√	√
Baobab	**	**	***	***	***	√	√	√	√
Celosia	**	*		*	*	√			
Cowpea	**	***	***	**	**	√	√	√	√
Dika	**	**	*	***	***	√	√		
Eggplant (Garden Egg)	**	*	**	**	**	√	√	√	√
Egusi	***	***	**	***	**	√	√		√
Enset	*	*	***	*	**			√	
Lablab	***	**	**	***	***	√	√	√	√
Locust Bean	**	**	***	**	***	√			
Long Bean	***	**	*	***	**	√	√	√	√
Marama	*	*	*	*	*				√
Moringa	***	***	**	***	**	√	√	√	
Native Potatoes	*	**	**	**	*	√	√	√	√
Okra	**	**	**	***	**	√	√	√	√
Shea	***	*	**	***	***	√			
Yambean	**	***	**	*	***	√	√	√	√

NB: The underlying justifications for these broad rankings are discussed in the following sections on Nutrition, Food Security, Rural Development, and Sustainable Landcare; greater detail is provided in the separate chapters on individual crops.

POTENTIAL ROLES FOR SELECTED AFRICAN VEGETABLES

To give some idea of their potential to help solve the great central issues of African humanitarian and economic development, we now highlight the relevance of the above-mentioned vegetables to four of Africa's biggest needs for human survival and social serenity: 1) nutrition, 2) food security, 3) rural prosperity, and 4) general landcare. Supporting evidence can be found in the respective chapters.

OVERCOMING MALNUTRITION

These days there is increasing appreciation for the class of food we call vegetables. Evidence is rising on all sides that a lack of vegetables increases susceptibility to infection and disease as well as to stunted physical and mental growth. Vegetables also help palliate the scourge of Africa's major health problems that are today exacerbated by the lack of a balanced diet.

By and large, vegetables supply dietary elements in which other food materials are deficient. For one thing, they are prime sources of minerals, being typically rich in calcium and iron and also contributing phosphorus, potassium, copper, magnesium, manganese, and cobalt. A few vegetables—notably legumes, such as various beans—are valuable sources of proteins. Furthermore, their cellulose, an indigestible carbohydrate, absorbs water and provides the bulk material, or roughage, that promotes intestinal function.

For another, vegetables are important sources of vitamins. Vitamin C, vitamin A, and folic acid are what make them essential to human well-being, but most vegetables also provide other B vitamins, including thiamine (B1), riboflavin (B2), pantothenic acid (B5) and pyridoxine (B6), which are important for brain function, immune-system operation, and the production of several important hormones. Many vegetables also contain small but useful amounts of vitamin E.

By choice or circumstance, the diets of many African communities are deficient in vitamins, minerals, and other nutrients vegetables supply. Through research and extension of traditional vegetables, much could be done to change the situation…cheaply and rapidly. Seen in Africa-wide perspective, this is likely to be at least as effective as any move to "biofortify" cereal grains.

It seems worth mentioning here that much can be achieved through school gardens, where children learn about growing vegetables while at the same time also attaining a better level of nutrition. Traditional vegetables would be worthy components of such enlightened school projects, supplying lessons far beyond the dignity of dirty fingers.

Below is a summary of the merits, *specifically in terms of fighting malnutrition*, of each of the 18 vegetables this book highlights. Additional

information, when available, is given in the separate chapters, but in general nutritional details for these crops are limited and at times of doubtful usefulness because of outmoded techniques. Even those vegetables for which there are no data are likely to have nutritional values in common with most vegetables.

Amaranth

In overall nutritional power, amaranth greens are not dissimilar from the better-known leafy vegetables. Their exceptional protein quality, however, makes them useful supplements to cereals and root foods. For this reason, India has been known to fortify weaning foods with amaranth-leaf flour. Moreover, the leaves are packed with vitamin A-forming carotenoids, whose lack blinds thousands of children each year. In addition, the leaves provide vitamin C and tend to accumulate dietary minerals, notably iron and calcium. All this puts amaranth greens among the finest potherbs for reducing the ravages of nutritional deficiencies.

Bambara Bean

Bambara bean is a rare examples of a complete food. It has such a nice balance of nutrition that people supposedly can live on it alone. Ripe or immature, the seed is roughly 60 percent carbohydrate, 20 percent protein, and 7 percent oil. In addition, the protein contains more of the nutritionally essential amino acid methionine than almost any other bean, making this peanut-like bean even more valuable. For these reasons this crop could be a superb tool for attacking Africa's under-nutrition.

Baobab

Baobab leaf provides at least three nutritious ingredients: protein, vitamins, and minerals, not to mention dietary fiber. The protein is of high quality, containing notable amounts of lysine and tryptophan. And baobab leaves contain very high levels of provitamin A, which means they could potentially prevent millions of children from going blind.

Celosia

Celosia leaves certainly contribute their share of nutrients, including calcium, phosphorus, iron, and vitamins, as well as not a little protein. Among people in the know, these dark-green leaves are especially valued for promoting physical stamina. Likely, they can play a part in reducing chronic malnutrition but so far there is no solid experience upon which to make a judgment.

Cowpea

Dried cowpea seed consists of protein (up to 24 percent) of good nutritional quality. The bean is nearly 2/3 complex carbohydrate, with some oil (up to as much as two percent), and minerals and nutrients of lesser stature. On top of that cowpea is palatable and relatively free of the kind of metabolites that suppress soybean's value in combating malnutrition. For all these reasons, this grain legume could have a fine future in more effectively balancing the diets of Africans by the millions.

Dika

Dika, too, offers good possibilities for lowering scandalous levels of chronic malnutrition. The kernel meal is high in oil and protein (including six of eight essential amino acids), and would make an exceptional nutritional tool in West and Central Africa where marasmus (the malnutrition caused by a lack of food energy) and kwashiorkor (the malnutrition caused by a lack of protein) are major baby killers. In addition, the fruit has more vitamin C than pineapple or orange and also has vitamin A in quantity. Collectively, these features make a strong case for more testing, more research, and horticultural development that might lead to many more purposeful dika plantings.

Eggplant (Garden Egg)

Although far from being nutritional powerhouses, these colorful egg-like fruits provide protein, vitamins, and minerals. By the standards of the modern Western world they are a dieter's dream: low in sodium, low in calories, high in dietary fiber, and a good source of potassium. For Africa, however, they probably lack the nutritional punch to knock out the malnutrition that threatens the lives of children.

Egusi

Wherever protein-calorie malnutrition remains chronic, egusi seed could provide an exceptional boost for public healthcare. More than half its weight is edible oil. Another 30 percent is a protein of high nutritional quality. The seed also contains important amounts of minerals and vitamins, especially thiamin and niacin. This is a nutritional combination of potent portent, considering that the crop can thrive where malnutrition among babies is rampant and infant formula is rare. It doesn't take much of any food that is half oil and almost a third protein to provide the calories and amino acids that stressed, sick, and fast-developing little bodies need each day. Egusi could thus be a vital tool against marasmus, kwashiorkor, and other nutritional debilitations.

Enset

On the face of it, enset flour is little more than pure starch. The crop is therefore more like a staple than a vegetable. Yet strangely, people in the enset zone of Ethiopia are renowned for superior nutritional status, perhaps because enset so effectively fulfills their quest for simple carbohydrates.

Lablab

With a crude-protein content of 20-28 percent, lablab seeds are worth considering in malnutrition prevention programs. In addition, the amino acids are moderately well balanced, with an especially high lysine content, which means that they help balance out diets that are over-heavy on the staples. The seeds are also a good source of energy. However, as with soybean, they contain antinutritional factors. The leaves, too, are rich in protein, as well as iron. Likely, this crop can play a big part in improving nutrition, but careful investigations are needed before proceeding on any mass scale.

Locust Bean

Locust beans make a concentrated food with a nice complement of protein, fat, sugar, starch, and fiber, not to mention vitamins and minerals. Lysine makes up about 7 percent of the protein, a level similar to that in whole egg, one of the gold standards of proteinaceous foods. The fat is of the unsaturated kind, the major fatty acid being linoleic—a nutritionally useful ingredient often deficient in the diets of the poor. The smelly fermented locust-seed product, dawadawa, is possibly more nutritious still, but the young who overwhelmingly make up the malnourished may not find it as appealing as everyone else does.

Long Bean

This vegetable is sometimes called poor-man's meat in Asia because it produces so prolifically and makes a filling meal. Long-bean pods, eaten like green beans, provide fairs amounts of provitamin A and vitamin C, and the leaves contain 25 percent protein of a high nutritional quality. Already well known in some places outside Africa, long bean seems like a ready tool for bolstering Africa's nutritional well-being.

Marama

On its face, marama is astoundingly promising for lifting nutritional levels in the dry zones. Its seeds rival soybean in both protein content and protein quality, and they far surpass soybean in edible oil content. On top of that, the tuber portion of the plant contains a remarkable 9 percent protein. Marama, however, is a wild plant of the southern African deserts and may prove

impossible to produce in quantity either there or elsewhere. At this time, the most appropriate actions involve cautious horticultural research and nutritional testing. This is a putative crop that first needs a foundation on which to build.

Moringa

In a few parts of Africa, various moringa products are already promoted as food additives. The pod provides *all* the essential amino acids; vitamins A, B, and C; and a wealth of minerals. Its high levels of iron and calcium make it particularly valuable for women young or old. The leaves are remarkable for methionine and cystine, vitamins A and C, calcium, and iron. In the Philippines, where moringa is exceptionally popular, these leaves are commonly boiled and fed to babies. They reportedly also increase lactation in mothers. Any foodstuff with such nutritional qualities could prove a potent means to fortify a malnourished continent, both directly and through mother's milk.

Native Potatoes

Native potatoes occur where a shortage of suitable vegetable crops now results in endemic malnutrition. They produce large amounts of good food from a small amount of ground. The tubers contain around twice the protein found in potatoes, and a meal can contribute most of a adult's daily requirement. A standard serving also provides a large percentage of the daily requirement of calcium and vitamin A, as well as more than the daily complement of iron. For a root crop, the content of essential amino acids and food-energy are notably high as well.

Okra

Okra provides three food products: pods, leaves, and seeds. All have dietary value. Half a cup of the cooked pods, for instance, provides nearly 10 percent of the recommended levels of vitamin B6 and folic acid, not to mention fair amounts of vitamins A and C. The leaves contain protein, calcium, iron, and vitamins A and C. The seeds are potentially a good source of an especially nutritious protein, rich in tryptophan and having adequate levels of the nutritionally vital sulfur-containing amino acids. Okra protein thus complements and fulfills that of cereal grains and legumes, not to mention of root crops.

Shea

Even though it is not a major portion of any meal, this solid vegetable fat has an importance to the inhabitants of the semiarid zone along the Sahara's southern edge that is difficult to overstate. It enhances the taste, texture, and

digestibility of the major regional dishes. This is not a vegetable like the others we describe, but for millions living in this harsh location, where food is difficult to produce and life hard to sustain, shea butter is a part of everyday existence. For the struggle against marasmus, this would seem a natural ally.

Yambean

African yambean is a classic in that it could benefit millions of the malnourished, but no one has yet championed its greater use. The seeds are about one-quarter protein, and the protein has essential-amino-acid levels likely to make it the soybean's nutritional equal. The tubers are nutritious too. Those swollen root tissues amount to 10 to 20 percent raw protein, which is of high nutritional quality. For children, especially, yambean may be valuable. Nibbling on the tasty raw tubers will provide a quality protein of a kind they cannot easily get elsewhere.

BOOSTING FOOD SECURITY

When considering the “facts of life” it is commonly forgotten that a primary one is the need to eat every day. Unfortunately, plants seldom provide their edible bounty on such a convenient schedule. This means that people who find their own food must withstand periods in which nothing can be gleaned from soil or shelves. In addition, for much of Africa the possibility of multi-year drought is a pervasive fear and a sometime purveyor of famine.

Sadly, those living in poverty have little margin for error: crop- and climate fluctuations or periodic natural disasters or human conflict quickly create conditions for catastrophe. And it is not realistic to expect that relief efforts can always succeed. Not surprisingly, though, there are ways indigenous vegetables can help fill even some of the longer gaps in the dietary continuum, both in normal and abnormal times.

Of special significance, here, is the fact that the native vegetables’ adaptive qualities were selected by Africans under precisely the variable conditions and climatic vulnerabilities of that continent.

Below is a summary of the merits, *specifically in terms of food security*, of each of this book’s 18 highlighted vegetables.

Amaranth

These plants already secure the food supply for millions. They are easy to produce and grow so fast that the first harvest can sometimes be gathered just three weeks after planting. Subsequently, several successive harvests can be made, and this aptitude for both jack-rabbit starts and for feats of endurance not only eases the farmer’s burden in filling the family stomachs, it creates huge yields in the kind of small spaces relegated to the destitute and disenfranchised.

Bambara Bean

Due to its dependable production, bambara bean has the potential to improve food security in many rural areas. Indeed, it promises to become a stable, low-cost, and profitable food crop for Africa’s small-scale farmers living where the rains are not to be trusted. Resilient and reliable, it commonly yields food from sites too hot and too dry for peanuts, maize, or even sorghum. It might truly prove an ideal insulator against starvation wherever rainfall is unreliable.

Baobab

Among vegetables, a food class renowned for short seasons and transitory availability, baobab is a leafy vegetable that keeps on producing throughout

the rainy season—often half the year. In addition, any surplus harvest can be dried. In desiccated form, the leaves keep well even under the pest and climatic pressures of rural Africa. Clearly, this is a food-security treasure.

Celosia

A supremely self-reliant and uncomplicated resource, celosia propagates easily, requires little care, and often reseeds itself like a weed. Its Malawian name means "eaten by lazy ones," a recognition that not only is it easy to produce but it cooks quickly and efficiently. As a back-up security support for subsistence farming this lowly herb seems to offer true value.

Cowpea

One of the more remarkable and precious things about this species is that certain of its cultivars mature with as little as 300 mm of rainfall. This makes it the grain legume of choice for the Sahelian zone and the contiguous savannas, both of which are surprisingly populated, erratically dry, and vulnerable to mass outbreaks of malnutrition and misery. Cowpea seeds provide quality protein and other essential nutrients that complement the otherwise unbalanced diets the poorest sectors are forced to stomach.

Dika

The fruits have traditionally been collected from wild trees in the forests, so not much has been reported about their likely ultimate contribution to food security. Nonetheless, harvesters gather dika nuts by the thousands of tons each year, and those dried kernels are especially stored for the hungry season.

Eggplant (Garden Egg)

This is a resource that is easy to raise, relatively free of disease and pests, and capable of providing a steady supply of both food and income. The plants are known for a capacity to furnish terrific amounts of food from a tiny space. Also, the fruits have a storage life up to three months. Having firm skins, they also transport well. Furthermore, this African eggplant can be dried and stored for later use, notably in emergencies such as when the growing season is finished and nothing fresh is available.

Egusi

Noteworthy is the fact that egusi seeds can be stored for long periods without particular trouble from pestilence or degradation. This is one oilseed that can supply food year-round. And it is a quality food: the oil making up the seed's largest nutritional component is polyunsaturated.

Enset

Enset's importance for poor-people's food security seems self-evident. Interviews with farmers suggest that Ethiopian peoples who depend on the plant NEVER suffer famine. Indeed, a family with just a small plot of enset supposedly will have food forever. This long-lived species represents natural food security, always available for general use, or for exclusive use in rare times when all other eatables fall short.

Lablab

This is not an exceptional food-security crop, but a well-established lablab plant's root system often penetrates into water sources more than 2 m deep, permitting luxurious growth to persist long after the rains have ended and the surface soil is parched. Because of its extended production season, the crop continues providing food, fodder, and soil protection long after other herbaceous species have dried and died.

Locust Bean

This is one of the best species for securing a supply of food when nature has other plans. Although locust beans are a part of the daily diet across a zone often devastated by drought, this tree also turns into a lifesaver during famine times. Its seeds contain protein, fat, sugar, starch, vitamins, and minerals, and are about as balanced and concentrated a food as could be devised. Add that they mature in the dry season, the traditional "hungry time," and their value as emergency food becomes plain. Even when drought has seared the landscape, this deep-rooted tree continues producing its foodstuffs, as if on its own schedule.

Long Bean

Long bean plants are succulent and therefore probably not the greatest security food, but they not only thrive in hot humid climates, they produce food very quickly. Indeed, the leaves can be harvested within three weeks of planting, and some types produce harvestable pods inside two months. The main varieties continue producing for months on end, thus giving rise to an extended harvest that keeps providing fresh food over long periods.

Marama

This protein and energy-rich species nourishes people in southern regions where rain is so slight and erratic that some years almost none whatever falls. It lives through such conditions, not to mention blistering summers, apparently with ease. In addition, it survives low winter temperatures, especially the freezing nights of the Kalahari. But as a continental food

source it hardly seems promising, owing to its lack of horticultural development and apparent narrow geographic range.

Moringa

A rugged, resilient tree species, moringa tends to produce well in marginal growing conditions and is a reliable source of greens in seasons and locations where few other vegetables produce much of anything. In West Africa the leaves appear at the end of the dry season, a time when other sources of leafy green vegetables have mostly died. All this adds up to a food-security gem.

Native Potatoes

These tubers, which are overwhelmingly employed as subsistence food, also make a good food-security insurance policy. They can, for example, be dried and set aside for the hungry times. These clonal crops are easy to handle and propagate. Taken all round, then, these ancient resources could prove good tools not only for reducing malnutrition and hunger, but for tiding African families through the times when other food is unavailable.

Okra

Although not normally grown under stressful conditions, the plant shows considerable tolerance to drought and heat, and should perform more reliably than most plant resources in Africa's savanna regions, where food supplies are currently often undependable.

Shea

Traditionally, this large and treasured tree, not unlike oak in general appearance, provided the primary edible vegetable fat to peoples inhabiting a vast tract of wooded grassland that is vulnerable to some of the worst droughts of the arable world. Nutritionally speaking, it is noteworthy for providing buttery kernels capable of providing a steady source of dietary energy year-round.

Yambean

With built-in adaptability to a wide range of climates and soils, African yambean is a reliable performer. It grows easily and is well suited to the hot wet tropics, an environment unfriendly to so many crops that people there suffer from a lack of healthful agronomic options.

FOSTERING RURAL DEVELOPMENT

Beyond their fundamental subsistence use, vegetables make good cash crops. They command relatively high prices and can be produced efficiently on a small scale. This makes them excellent resources for relieving rural poverty. Like fruits, they provide farmers an easy entry into the world of commerce and into at least the prospect of prosperity. Indeed, anyone with access to land can grow vegetables.

For many rural Africans, these plants and their products provide opportunities for economic gain. Many species are already grown at home and sold in local markets; children also collect them to sell within their village. Nevertheless, supplies now reaching the cities are generally considered to fall far short of the natural demand.

Mostly, vegetables are produced by women, peddled by women, and prepared and served by women. They therefore offer a convenient lever for lifting female existence to a higher plane. This is of broader importance than may be apparent: Improve the lives of women, and you improve the lives of babies born and unborn. In a related vein, vegetables offer good opportunities for gender-oriented innovation and female-led entrepreneurial enterprises.

Below is a summary of the merits, *specifically in terms of improving rural development*, of each of the 18 vegetables highlighted in this book.

Amaranth

In the lives of the rural poor this low-cost crop is notably important as a source of income. Many desperate farm families grow more amaranth for sale than for their own subsistence. Women are the prime producers. The crop is mostly grown, harvested, and marketed close to home, and it forms a crucial part of both the rural economy and the female existence. Thus if science can boost output or reduce production costs it will disproportionately benefit not only the group most at risk but also the one most likely to support society.

Bambara Bean

This crop has outstanding commercial possibilities. Beyond the normal farm and village sales, commercial food processing is likely to open up buoyant new bambara-bean markets. In this regard, it is notable that the canned product seems to have high marketing potential in urban areas. Across Africa there is room for bambara-bean-processing enterprises, which will create new outlets for farmers and boost income opportunities for rural areas. There's even potential for world exports.

Baobab

Africa's most emblematic tree is also a likely vehicle for poverty prevention. Traditionally, baobab has not been deliberately cultivated, merely encouraged and protected. However, farmers in West Africa have recently begun producing it in an organized way for vegetable markets in the city. This is succeeding because where baobab trees aren't available for the picking, the leaves necessary for the evening meal must be purchased. For city-dwellers finding that can become a never-ending struggle: Making baobab-leaf sauce can at times cost the equivalent of a day's work. On the other hand, sales continue brisk and country-women derive important income from selling the leaves.

Celosia

Celosia seems a promising green for commercial cultivation in the hot humid tropics, especially during the rainy season, when other crops succumb to molds, mildews, and like maladies. It can be very high yielding and its young leaves have a good taste and a good nutritional value. Celosia is already southern Nigeria's most important leaf vegetable and is raised in myriad home gardens and farm plots both for the family and the local marketplace.

Cowpea

Beyond its value to the malnourished, this is a high-potential cash crop. At present it is the second most important grain legume across the African continent; only peanut—a scion of South America—occupies more African farmland. Nigeria, the biggest producer, grows several million tons a year, yet its potential across a broader swath of Africa is scarcely considered.

Dika

Through dika, millions of farmers already earn a critical income. They sell the fruit for juice, jam, jellies, and the fresh market. In addition they sell the oil to factories making margarine, soap, or pharmaceuticals. The greatest profit center of all, however, is in the defatted kernel meal. This shelf-stable soup ingredient even has export potential. Indeed, entrepreneurial West Africans living in the United States already hawk molded ogbono cubes, mostly over the internet.

Eggplant (Garden Egg)

Throughout Africa, local garden eggs provide a continuing source of income for farmers. In rural districts from Senegal to Mozambique women are commonly seen hefting baskets of them on their heads to sell in nearby villages or townships. Yet these vegetables have untapped commercial

promise and could become the cornerstone of localized rural economic development drives. There is also perhaps potential for exporting African eggfruits to Europe and North America and thereby earning hard currency.

Egusi

Egusi seed is in high demand in tropical markets, especially those in urban areas. Almost all the food sellers in Benin, Cameroon, Ghana, Nigeria, Togo, and the other nearby nations display it for sale. Egusi is also peddled over the Internet to aficionados around the world. From greater production and greater profitability women would be special beneficiaries. They are the main growers and, due to the relatively high cash income they receive, egusi is already a sort of female treasure.

Enset

Enset's importance extends far beyond food; every part is useful for something. Farmers in Ethiopia's southern highlands declare that, "enset is our food, our clothes, our beds, our houses, our cattle feed, and our plates." In other words, this is a crop of life; like coconut it provides a basis for subsistence survival. Although much is sold in Addis Ababa, whether the crop can be harnessed for commercial purposes more widely in Africa is far from certain.

Lablab

The forms of lablab that have been developed as green vegetables are promising profit-makers, producing huge yields of pods (up to 7.5 tons per hectare) that look and taste good, and doing it quite quickly (4 months). In addition, the dry seeds are becoming commercially important in Australia, where it is claimed that they are suitable even for export (mainly as livestock feed), like some sort of southern-hemisphere soybean counterpart.

Locust Bean

Across West Africa locust seed is a major item of commerce, as is its famed fermented paste, dawadawa. These together constitute an important economic activity for women. Production of the pungent dawadawa is a traditional family craft and, although most is produced for home use, it also commonly ends up sold in local markets.

Long Bean

This productive legume yields a lot of food in a very small space. On worn-out soils it is said to out-produce peanuts. A true legume, it is largely independent of fertilizer....enriching soil by trapping atmospheric nitrogen in bacteria-filled nodules on its roots. It not only fits into African farming, it

also fits into African cuisine, especially into the vegetable-laden sauces and relishes. These tasty, universally admired treats therefore hold out the prospect of a good income for those who choose to grow long bean for profit.

Marama

As of now, this is too far from being a commercial crop to promise purely economic benefits.

Moringa

Potentially there is profit to be made from what at present is a quintessential subsistence resource. First, moringa is a fast-growing, high-yielding oilseed. Second, the trunk is gaining importance as a raw material for papermaking. And third, pods and leaves could be produced for the fresh market or for processing. Adding to its rural-development benefits is the discovery that the seeds can help purify water. There are indications, too, that moringa-seed extracts make useful treatments against skin complaints. Moringa is also valuable as feed for livestock.

Native Potatoes

Although native potato is not a cash crop in the normal sense, part of the harvest is commonly put up for sale in the villages. Collectively, African women derive income thereby. It is notable that the crop occurs in areas of low agricultural potential across the continent's most needy regions. In addition, prepared food products seem quite possible. Native potato therefore holds the potential to provide more income to those who produce, collect, and process the tubers, most of them female.

Okra

Okra could have an unexpectedly important future as an industrial crop. There seems to be little difficulty in producing the plant on any particular scale. In the United States, for example, some is already produced in quantities big enough for the pods to be canned, frozen, or brined for supermarkets coast to coast. In addition, okra could, at least in principle, have a future producing things that are unexpected from a vegetable crop, including construction materials, handicrafts, forage, and fuel.

Shea

Shea is often a principal economic resource underpinning the lives of those inhabiting vast areas where little else saleable can be found or farmed. According to estimates, the tree provides more than half of all women's income in the rural Sahel. Foreign exchange is also earned: both seed-

kernels and the butter are shipped to Europe and Japan, where they are processed into baking fat, margarine, cocoa-butter substitutes, and various highly touted beauty aids. Some of these are appearing in North America too.

Yambean

Possibly the African yambean will make a valuable cash crop across regions that desperately need a farm-based fulcrum for leveraging rural development upwards. The highly efficient way in which it absorbs nitrogen makes it an especially attractive tool for helping those who suffer due to worn out soil. The tuber yield is generally high and can undoubtedly be raised—possibly dramatically—merely by preliminary research attention. But as of now there is not much documented experience this grossly neglected resource, so the future cannot be judged with any clarity.

SUSTAINABLE LANDCARE

After decades of focusing on fewer and fewer farmed foods, agriculture is once again promoting a diversified "product line." At the same time, numerous farming techniques are being discovered—or rediscovered—that yield bounteous crops reliably while leaving the land better off than before the crop was grown. Many of these technologies require little capital investment, making them ideal for the cash-poor countryside. Peering forward from today's limited perspectives on diversity and sustainability, it seems likely African vegetables provide opportunities for more sustainable land use, in large measure because of the relative gentleness with which they treat the land. In addition, they provide ecosystem services: pollen and nectar for bees, for instance, or effectively swath the soil. In addition, their increased use acts like an in-situ conservation program that, at least in some measure, helps preserve Africa's ancient heritage of food plant genes. This is important because the diversity in these crops is diminishing and essentially nothing is being done to conserve them in a comprehensive manner.

Below is a summary of the merits, *specifically in terms of sustainable landcare*, of each of the 18 vegetables this book highlights.

Amaranth

Amaranths demonstrate exceptional vitality in many types of sites. Most are pioneer species, whose niche in nature is the quick colonization of disturbed land. They use the C4 photosynthetic mechanism, common in arid-land species, which enables them to survive not only hot weather but dry weather as well. Given some ingenuity, it seems they could be turned to good account for quickly protecting naked land until it can be re-clothed with a longer lasting cover.

Bambara Bean

Bambara bean epitomizes the idealists' ideal of a "sustainable crop." Every plot is a mixture of genetic diversity and no plant is fertilized or sprayed. In addition, the species' nitrogen-fixing capacity helps boost soil fertility, naturally. The crop can even be used as a soil conditioner. And beyond all that, it thrives in laterite, the ancient, reddish acidic soil substrate that is toxic to many plants and is an underlying curse of tropical agriculture. Programs aiming to achieve sustainable farming in Africa could find bambara bean a good foundation around which to base their programs.

Baobab

Extending the use of baobab leaf to regions beyond West Africa offers possibilities for enhancing both the crop and the environment, not to

mention nutrition and rural prosperity. Already often likened to “Africa’s soul,” this is a tree that can tap into the heart of many of the continent’s most basic needs: humanitarian, economic, *and environmental*.

Celosia

Humidity and heavy rainfall fail to limit growth, so celosia is commonly cultivated during the wet season when other crops collapse due to weather or wanton maladies. Because of its tolerance to conditions both wet and dry, and because it is usually unaffected by pests, diseases, or soil type, it is among the most promising greens for unforgiving or fickle growing conditions. The plants spring up with surprising vigor from tiny seed. They have special promise for cultivation next to millions of huts and hovels, whose occupants can then pluck off some leaves each day and drop them into the soup pot. This is about as gentle an agriculture as is possible.

Cowpea

One of the best landcare food crops, cowpea has deep roots that help stabilize the soil as well as dense foliage that shades and covers the surface and preserves moisture. Both these below-ground and above-ground traits are of special importance in the dry zones, where moisture is at a premium, soil is fragile, and wind a dirt-scouring demon. Like most other legumes, cowpea fixes atmospheric nitrogen, thus lifting the nitrogen content in the soil around it. It is often intercropped with sorghum, millet, or maize, as much to foster their good health as to furnish its own beans.

Dika

Dika thrives in places such as the evergreen forests of Central Africa, and its special adaptation to heat and humidity raises the possibility of improved forms becoming employed in the form of an eco-friendly crop for dense, moist, heavily shaded conditions. Also, in southeast Nigeria, dika has been extensively planted to control soil erosion. In the future, it might even help reduce the pressures to damage the ecosystem whose future worries so many today: the African rainforest. People with dika trees will have few pressures to seek new land to cultivate.

Eggplant (Garden Egg)

This very adaptable crop can be grown in widely different climates. The plants are fast maturing and produce several harvests of fruits, so they yield both quick results and extended ones. This notably benefits soil conservation activities, especially when eggplant is used to cover bare soil in the spaces between the farm’s main crops. They tend to tolerate shade and so can be fitted in around various taller plants, such as bananas, cassava, and trees.

They are suited to various infertile and difficult soils, and are likely candidates for wringing food and income from numerous kinds of "agricultural wastelands." All this makes garden eggs good for the ground.

Egusi

Egusi is easy to grow. Indeed, it survives on barren sites, not to mention some of the driest and most climatically challenged locales. Further, it blankets the soil and helps protect the surface from damaging rain and wind. Most of all, though, this vigorous annual suppresses weeds. The plantings may need a month or so of tending, but after that they typically remain weed free.

Enset

Surprisingly, farmers often do little to maintain or improve their enset plots, other than add manure. Although they incorporated exceptional quantities of animal waste, it is still fair to say that the plant provides a long-term sustainable food supply with minimal inputs. It is said that many enset fields have been in continuous production for decades, if not centuries, and yet they remain productive, stable, and unfailing. If any food crops can match that record we've not heard of them.

Lablab

Beyond all its uses for food and fodder, the plant can be used advantageously to provide organic matter and fix soil nitrogen, thereby boosting subsequent crop yields in a cheap and environmentally friendly manner. It is possible that lablab could become an essential part of certain sustainable farming systems. Managers of coconut, rubber, and oil-palm plantations know from long experience that it is one of the most valuable, trouble-free, and trustworthy of all leguminous herbs for suppressing weeds and rejuvenating worn-out soils. To them the food is a trivial matter by contrast with the environmental advantage.

Locust Bean

It is noteworthy that the locust tree tolerates a wide range of alluvial, sandy, and lateritic soils. It also resists pests and diseases, survives fires, and thrives in full sun and fearsome tropical heat. Moreover, its deep roots make it almost independent of equable rainfall. All this would seem to make locust an ideal candidate for mass planting in appropriate parts of Africa, notably the once-forested savannas. The trees also promise to make many now sun-drenched streets and highways into shady food waysides. All in all, more locust beans—whether planted for provisions or protection—add up to more hope for a better continent.

Long Bean

Although nothing is reported about long bean *per se*, other cowpea forms fix nitrogen efficiently and make useful living mulches for restoring barren land. Long bean should do the same. Indeed, it has been called a nearly perfect match for Africa's soil, Africa's weather, and Africa's people. The seeds of select strains also cook fast, an important consideration wherever fuelwood is scarce and expensive, as it is in that vast parched crescent of concern between Senegal and Mozambique.

Marama

In principle at least marama should prove ideal in the vulnerable drought-prone sandy zone of southern Africa. But not enough is known about this crop to suggest large-scale "environmental" plantings.

Moringa

This raggedy species looks like a forester's nightmare but its ability to thrive in wastelands and provide rapid tree cover could make it the choice for many reforestation projects. Likely, too, it is a good nurse crop for slower-growing species that eventually dominate the site. In addition, moringa is an excellent candidate for fast-track beautification of streets, slums, and squatter settlements. The presence of the living tree, though far from spectacular, improves the scene as well as the surroundings—providing shade and shelter from the elements.

Native Potatoes

While much remains to be learned about the native potatoes themselves, a recent report declares that: "root crops will be many things to many people by 2020." Driving the authors to this deduction is the adaptation of root crops to marginal environments, their vital role in promoting food security at the household level, and their flexibility in mixed farming systems. There's no reason to doubt that such conclusions also apply to these little-known root crops and that the African landscape will benefit thereby.

Okra

By and large, okra seems an eco-friendly crop. Though not a legume, it is not destructive to the soil. Quite the opposite: At the end of the harvest season, the foliage and stems can weigh 27 tons per hectare. With fuel costs rising worldwide, okra biomass seems likely to become more notably useful than even now, especially as more tropical forests are destroyed.

Shea

Shea (and locust) commonly provide the only tree cover across a vast area that is vulnerable to desertification. A self-reliant perennial species providing food in the dry, drought-seared savanna would seem the ultimate in sustainable agriculture. Making the most of the difficult climate and the most of the largely worn-out soil, the trees need little care and may live for centuries. The time-honored farm/park landscape covering major portions of the Sahel is said to be a perfect example of large-scale agroforestry at its best.

Yambean

African yambean could well prove to have a superb soil-repairing capacity. Already, there is preliminary evidence that it could be excellent for crop rotations, for ground cover, and for binding soil. The plant thus seems a fine candidate for sustainable development purposes. This is, in other words, a food source that supports itself while helping both the soils beneath and the species surrounding and succeeding it.

* * *

The brief synopses above have focused on the promise of these African vegetables. The chapters that follow, from which these summaries were pulled, offer additional detail on both the promise and challenges faced by those choosing to work with these plants.

DESCRIPTIONS AND ASSESSMENTS OF INDIVIDUAL SPECIES

1

AMARANTH

To the world of science, vegetable amaranths verge on the invisible. As far as international statistics are concerned, this crop doesn't exist. Books highlighting world food plants, even those dealing specifically with vegetables, largely ignore it or accord only the briefest mention. Not surprisingly, then, researchers engaged in improving global food supplies pay little heed. Indeed, most may have never heard of a vegetable amaranth.

Yet if this leaf crop seems invisible, it is only because it is hidden in plain sight. At least fifty tropical countries grow vegetable amaranths, and in quantities that are far from small. Throughout the humid lowlands of Africa and Asia, for instance, these are arguably the most widely eaten boiled greens. During the production season, amaranth leaves provide some African societies with as much as 25 percent of their daily protein. In parts of West Africa the tender young seedlings are pulled up by the roots and sold in town markets by the thousands of tons annually. Other parts of the continent also rely on them to a similar degree. A definitive review of southern Africa's native foods, for example, clearly lays out their status: "Of all the wild edible plants eaten in southern Africa, few if any are as well known and widely used as amaranths."[1]

Amaranths are a poor people's resource, and the plants are often dismissed as "lowly" and ignored as if, like poverty itself, they should be avoided at all costs. As a United States Department of Agriculture bulletin points out, few species of vegetables are so looked down upon. Several languages include the demeaning phrase "not worth an amaranth." Indeed, the plants are sometimes regarded as being fit only for pigs ("pigweed" is the common name for one despised American species).

At first sight, this scorn seems almost universal. *Amaranthus* is one of the few genera whose species were domesticated in both the Old and New World.[2] It has provided very ancient potherbs (boiled greens) not only to Africa but to Asia and the Americas as well. Nowadays the various species from the different tropical regions are pretty much scrambled up genetically, so that the origins of any given amaranth plant remain (at least for the

[1] Fox, F.W. and M.E. Norwood Young. 1982. *Food from the Veld: Edible Wild Plants of Southern Africa*. Delta Books, (Pty) Ltd., Johannesburg.

[2] Many of the more than fifty *Amaranthus* species in both tropical and temperate regions are eaten, but only a dozen or so can be considered domesticated.

Vegetable amaranths are probably the most widely eaten boiled greens throughout Africa's humid lowlands. They secure the food supply for millions. The leaves and stems make excellent boiled vegetables with soft texture, mild flavor, and no trace of bitterness. (Jim Rakocy)

moment) fuzzy.[3] This seems to be especially the case in Africa.

Amaranth leaves and stems make boiled vegetables with soft texture, mild flavor, and no trace of bitterness. In taste tests at the U.S. Department of Agriculture in Beltsville, Maryland, most of the 60 participants said that cooked amaranth leaves tasted at least as good as spinach. Some likened the taste to that of artichoke.

Given the food-production experts' lack of interest, one might imagine these plants to be difficult to grow and unappealing to the growers. But such is not the case. Amaranths produce seeds aplenty and their seedlings emerge so rapidly and sprout with such vigor that the first crop of leaves is sometimes harvested within three weeks of planting. Furthermore, new generations of leaves keep materializing, so that many harvests can be made before replanting becomes necessary. This aptitude for extended production not only eases the farmer's burden, it leads to huge yields: one test produced 10 tons of edible greens per hectare in a 30-40 day harvest period.

Given their general lack of recognition, one might imagine these lowly

[3] Generally the wild species are considered to have hybridized frequently with the cultivated and thus produced a series of intermediate types.

plants to lack nutritional power. Actually, they have high food value. The leaves have an exceptional protein quality, (25 percent for *Amaranthus cruentus*) reportedly containing more lysine (about 0.8 percent for *A. cruentus*)] than quality-protein maize (high-lysine corn) and more methionine than soybean meal. In addition, vitamins A and C occur in good quantities. Minerals such as calcium and iron are also present in abundance.

Given their lack of recognition one might imagine these lowly plants to possess such strict climatic and soil requirements that they grow well only in limited locations. Once more, however, the truth is quite the reverse. Amaranths demonstrate exceptional vitality in many types of sites. Most are pioneer species, whose niche in nature is the quick colonization of disturbed land. They therefore produce a huge number of fast germinating seeds and this may be why a classically minded botanist named them amaranth, an Ancient Greek word meaning “life everlasting.”[4] The plants use the C4 photosynthetic mechanism, common in arid-land species, which enables them to thrive not only in hot weather but in dry weather as well.

Although in most of the lowland tropics the upper crust may hold vegetable amaranths in low esteem, in Caribbean nations the whole society honors these plants. The humble leaves are important ingredients in Caribbean cooking, especially in the famous regional favorite known as callaloo,[5] which is normally a gumbo-like stew or a spinach-like vegetable dish that often features the texture of Africa’s okra (see Chapter 16). Callaloo is so central to the diet that it has become almost synonymous with the Caribbean image. The word has entered everyday talk as a word denoting the unique blending of food, language, music, and peoples constituting Creole culture. The name callaloo is appended to restaurants, magazines, shows, songs, bands, books, and more. It is an appellation bestowed with pride.

In China and Southeast Asia, a region renowned for quality vegetables, one amaranth—Chinese spinach, *Amaranthus tricolor*—ranks among the very best. Farmers in Hong Kong, for example, grow at least six types: pointed leaved, round leaved, red leaved, white leaved, green leaved, and horse’s teeth. Those in Taiwan grow a type called tiger leaf, which has green leaves with a red stripe down the center.[6] They’re not only very pretty, they’re very tasty.

The fact that vegetable amaranths aren’t honored like this everywhere is a shame. These classic poor-people’s plants provide a perfect botanical tool

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[4] The family was so named by Antoine Laurent de Jussieu (1748-1836), a remarkable botanist who named 100 plant families. The power of his insight can be judged from the fact that 76 of the names, including Amaranthaceae, remain in use to this day.

[5] Variously spelled callaloo, calaloo, callalou, callalou, callalu, and calalu. Various Caribbean countries make callaloo from both amaranth *and* other plant leaves, especially Asia’s dasheen (taro); in Jamaica, however, amaranth and callaloo are synonymous.

[6] Herklots, G.A.C. 1972. *Vegetables in South-East Asia*. Hafner Press. New York

for helping the most nutritionally challenged strata of society. Taken all round, they represent a sort of do-it-yourself kit to good nutrition and lend themselves ideally to subsistence conditions. With them, little horticultural experience is needed before the benefits of better nutrition can be enjoyed. Although insect pests and diseases can be problematic, few if any tropical vegetables are easier to grow. In favorable locations amaranths produce food almost without attention.

Seen in overall perspective, these fighters offer frontline armaments in the battle to feed properly a malnourished world. They yield protein and other nutrients efficiently. They afford abundant provitamin A (beta-carotene), a nutrient vital to the millions of malnourished children now at risk of blindness. And they do it quickly.

In summary, amaranths are an important market vegetable for many farmers, but their main benefits are humanitarian ones. Without these humble plants, the hidden hunger of malnutrition would be much worse. With them in greater use, it can be greatly lessened.

PROSPECTS

Although vegetable amaranths have yet to catch the attention of most researchers and scientific establishments, few crops can match them for effectiveness in nutritional interventions. In places such as Africa they offer an easy entree intervention because they are even now consumed by, admired by, and sought by the rural peoples for whom food insecurity is a daily peril.

Within Africa

Humid Areas Excellent. *Amaranthus* species are of course already used widely as potherbs in the humid lowland tropics. Over the years, growers have selected types with leaves and stems of high palatability. The mild taste, high yields, high nutritive value, and ability to withstand hot climates make them popular. In flavor, food value, and “farmability,” they are the best of all tropical potherbs.

Dry Areas Modest. Given their C4 photosynthesis, amaranths thrive, or at least survive, under droughty conditions. However, for good production under dry conditions supplemental water must be applied. The plants tend to

grow very rapidly and they have high leaf areas (and thus high evaporation losses), so to attain top production and maximum palatability they require

ample water.

Upland Areas Good. With a fast-growing leaf crop like this, altitude is little barrier. Amaranth was a mainstay of ancient South American civilizations, produced at about the highest elevations known to agriculture.

Beyond Africa

Nothing restricts these plants to Africa. Prospects elsewhere are excellent. Indeed, the leafy amaranths have reached their greatest development in Asia. Furthermore, many species from this genus are cultivated in Mexico as well as in Central and South America. And in the Caribbean, of course, they are a mainstay of the traditional cuisine.

USES

This is a multiple-duty crop.

Leaves Leaves, young stems, and young inflorescences are eaten as potherbs. Although much of the pigment leaches out on boiling, the leaves retain a pleasant green color. They soften up readily, requiring only a few minutes cooking, which helps avoid excessive nutrient loss. Unlike some African potherbs, they need no added soda or potash to make them palatable. The leaf is also tossed into soups and stews. The boiled leaves may be rubbed through a fine sieve and served as a puree.

Salad Plant Very young leaves may be used in a mixed salad. Sometimes the whole plant is pulled up after it has developed eight or twelve leaves, and used directly in salads. The leaves, their petioles (stalks), and the plant's young growing tips are sometimes used in fresh green salads also. The flowers, however, are inedible.

Seeds Several species, including *Amaranthus cruentus*, *A. hypochondriacus*, and *A. caudatus* are grown for their grain-like seeds. Although small, these seeds occur in prodigious quantities. In carbohydrate content they equal cereals such as wheat, but have more protein (over 17 percent in some strains) and more oil. When heated, amaranth grains burst and take on a toasted flavor not unlike that of popcorn, which is very appealing. However, in many areas, they are more often parched and milled into flour. Bread made this way has a delicate, nutty flavor and is used notably by gluten-sensitive individuals. Pancake-like chapatis made from

amaranth are a staple in the Himalayan foothills.

Stems While most leaf amaranths are about 60 cm high, some varieties reach 2 m. It is reported that Singaporeans peel the stem of one of these tall forms and eat it separately. The report notes that to the taste buds they are "excellent."[7] In Bangladesh, special cultivars (of *Amaranthus cruentus*) are grown for the stems (food).

Decoration Amaranths are well known ornamentals, used worldwide to brighten window boxes, gardens, parks, and public buildings. The flowers can be strikingly attractive with bright colors and showy form.[8] Even without flowers some types are decorative. Certain amaranths have red striations in their green leaves due to the presence of anthocyanins. These can be very attractive and (like the tiger leaf variety in Taiwan) edible too.

Feeds Vegetable amaranth can also be used in feedlots for cattle or other intensively reared animals. In the early 1990s a husband-and-wife scientific team carried seed from Pennsylvania back home to China. The seed was from grain amaranths, and they expected to foster a new cereal-like food crop for their country. Instead, Chinese farmers adopted it for forage. Subsequently, it has become very popular in every one of the 29 provinces and is now grown by an estimated one million farmers who keep a pig or two around the house.

Other Uses It is reported that in South Africa's Queenstown district amaranth greens are eaten only by women, who believe—perhaps with good reason—that the young tops promote the flow of milk. The attractive flowers make *Amaranthus cruentus* a suitable species for honey production.

NUTRITION

The nutritional quality of amaranth greens is not dissimilar from that of better-known leafy vegetables. However, they tend to accumulate more minerals, notably iron and calcium, and amaranth greens rank at the top when measured against other potherbs.

Their exceptional protein quality makes them useful supplements to cereals and root foods. Protein levels in the leaves are reported around 30

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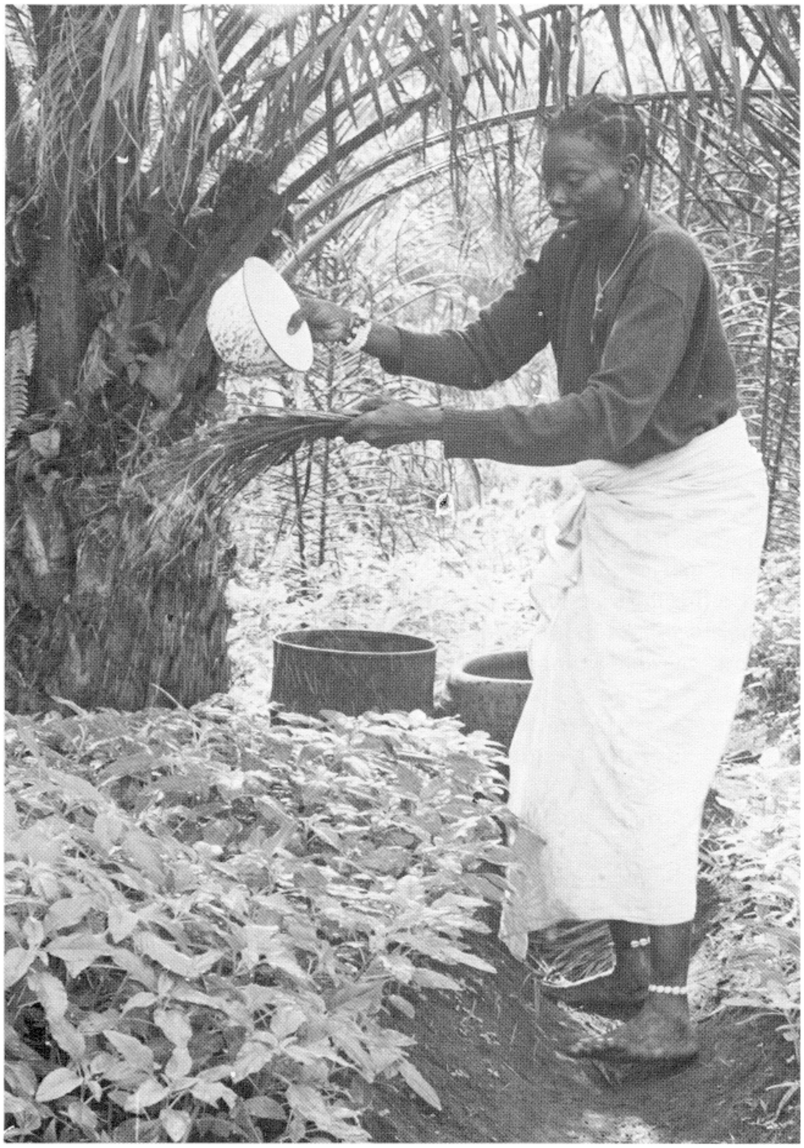
[7] Herklots, 1972

[8] These ornamental types go by many flowery names, including love-lies-bleeding, prince's feather, red amaranth, blood amaranth, cockscomb, Hell's curse, and Jacob's coat.

percent.[9] Protein quality is high as well. The amino acid composition of *Amaranthus hybridus* leaf protein, for example, shows a chemical score of 71, comparable to spinach. Elevated levels of the nutritionally critical amino acid lysine have been found in the leaves of 13 amaranth species. This makes it leaf protein a very good supplement to cereal grain. In India, weaning foods have been fortified with amaranth leaf flour.

[9] These are dry-weight basis. The figures were 27 percent for *Amaranthus blitum*, 28 percent for *A. hybridus*, 30 percent for *A. caudatus*, and 33 percent for *A. tricolor*.



This shade-loving crop can be fitted in around various taller plants, such as bananas, cassava, and trees. Amaranth greens are mostly grown, harvested, and marketed close to home, and women are the prime producers. Indeed, in several dozen nations this popular plant forms a crucial part of both rural economy and female existence. Here in Benin, a villager uses palm leaves and a bowl of water to sprinkle the amaranth bed in her home garden. (G.J.H. Grubben)

Vegetable amaranths are important sources of vitamin C as well as abundant precursors for producing vitamin A, whose lack blinds thousands of children each year.[10]

The minerals of importance in amaranth leaves are calcium and iron. Some doubt exists as to their availability in the human body, yet the contribution to people deficient in iron seems to be considerable.

HORTICULTURE

Amaranth is an important market vegetable grown by professional vegetable farmers. It is estimated that in Indonesia 20,000 hectares are planted per year. Amaranths are also cultivated in home gardens for family use, with any small surplus being carried to the village market in the form of tiny bundles of plants tied in bush fiber. The plants are sown virtually year-round in the tropics, and multiple cropping is possible due to its short life cycle (about 8 weeks).

Propagation is generally by direct seeding. Normally, the small black seed is broadcast very thinly (a seeding rate of 2 g per m^2 has been suggested) on prepared beds. The tiny seeds are covered with a little soil (a depth of a little less than a centimeter being recommended). The seed may be sown in nursery beds and subsequently transplanted to the field as seedlings.

Given sufficient rainfall and warm weather, growth is rapid. Within a month, indeed often within three weeks, the seedlings are big enough for eating or for transplanting. Typically, the plots are thinned at this stage, leaving the strongest and best plants. The seedlings weeded out are usually quickly washed and dumped into the cooking pot, roots and all.

Various expedients are employed to prolong leaf production. Repeated pruning is one. Another is pinching out the plant's growing tip, which 1) forces branching and the production of new and tender lateral growth and 2) suppresses any tendency toward early flowering. Keeping the plants thoroughly watered is a third method for extending the season. This lessens any tendency toward drought stress, which can trigger early flowering.

No matter what methods are used, eventually every plant proceeds to flower. Their value for food then plummets, and the plants are removed or let go for seed.

Fertilization with nitrogen stimulates vegetative growth and boosts yield substantially. To generate the greatest amount of the tenderest leaves, the

[10] According to the USDA, a 100g bowl of cooked leaves can provide more than half the daily adult needs for vitamin A; see www.ars.usda.gov/nutrientdata for additional information on thousands of foods, including a few in this report.

plants should be well watered and the soil fertilized, preferably with manure, compost, or nitrogenous fertilizer, during the period of active growth.

HARVESTING AND HANDLING

The plants grow rapidly and may be harvested when they reach a height of 30 to 60 cm. Although the whole plant can be uprooted, most are cut back, which both produces a harvest of leaves and encourages lateral growth. As many as 10 weekly harvests have been reported.

If the entire plant is harvested, a garden plot of 10 m^2 can yield 20 to 25 kg of tasty vegetable. If the leaves and lateral shoots are picked individually several times over, the same small plot can average 30 to 60 kg total yield. On a per-hectare basis, vegetable amaranth yields are generally in the range of 4 to 14 tons green weight. However, harvests as high as 40 tons per hectare have been reported.[11]

It is traditional in West Africa to soak the plant in water before toting it to market. This gives the leaves a fresh look. Typically the leaves are arranged in bunches, spread on a raffia tray, and hawked in market stalls or in the street. Since they lose moisture rapidly, the leaves are regularly sprinkled with water whilst awaiting a buyer.

LIMITATIONS

The grain's small size makes this crop tricky to plant. To ensure good germination the seeds must be close to the soil surface, which means that a hard rain or even a flush of irrigation water can wash them all away. The whole planting is thus often protected with a thin covering of grass mulch, which is removed after germination. This vulnerability is also a reason why some farmers sow the seeds in nursery beds, where the plants can be crammed together and protected fairly easily. Then, when the plants are beyond this danger, the farmer transplants them into the production plot. This is a particularly useful method to use during the rainy season.

The tiny seeds—about the size of sand grains—are also difficult to spread evenly across the soil surface. To get around this, the seeds are mixed with sand. Sowing the combination helps space out the plants and attains uniform dispersal.

Slugs and snails often severely damage young plantings, but the worst enemies of amaranth leaves are leaf-chewing insects. Larvae of moths and butterflies, as well as leafhoppers, leaf miners, grasshoppers, and leaf-

[11] Yields vary with the cultivar. In a test in the Virgin Islands, for example, the yield of fresh edible leaf was almost 1.2 kg per m^2 for one cultivar ('Callaloo') and merely 240 g per m^2 for another ('Greenleaf'). In this trial, the number of days from planting to first harvest ranged from 40 to 47 days. Palada, M.C. and S.M.A. Crossman. 1999. Evaluation of tropical leaf vegetables in the Virgin Islands. Pp. 388–393 in J. Janick, ed., *Perspectives on New Crops and New Uses*. ASHS Press, Alexandria, Virginia.

feeding beetles may very quickly decimate a planting. This is a problem without a universal solution at present. One useful practice is to cover the bed with a screen fine enough to keep the creatures out. This is of course cumbersome and tedious, but can be effective in the tiny plots in which vegetable amaranths are typically grown. Commericially, some amaranths are grown in screen or net houses that keep out all insects.

Diseases are also a problem. The plants are susceptible to viruses as well as fungal maladies, especially when they are young and the weather is damp. Generally speaking, vegetable amaranths grow poorly during long periods of cloudy, wet weather. During monsoon, for example, diseases such as damping-off (from *Pythium* and *Rhizoctonia*) can become serious. To reduce such diseases, the seedbeds must be well drained and located in sunny sites. Manuring can reduce or eliminate some of the attacks by strengthening the plants. Various fungicides have been successful also.

The C4 form of photosynthesis lends *Amaranthus* species a special competitive edge, to which is attributed their wide geographic dispersal and compatibility with diverse conditions. This is also why many amaranth species have turned into weeds. They are not, however, monsters of the weed world, just commonplace companions that pop up in the strangest spots, and in some of which they're unwanted.

Although the fresh leaves of some vegetable cultivars can glow with something akin to red fire, when they are boiled the brilliant pigment dissolves in the hot water. The leaves come out emerald green, but the cooking water turns dark and far from pretty.

That cooking water should be tossed out because it contains more than just pigment. All leafy vegetables accumulate antinutritional factors, including oxalic acid, betacyanins, cyanogenic compounds, saponins, sesquiterpenes, polyphenols, and alkaloids such as betaine. Amaranth is no exception, and all these compounds, which interfere with our ability to utilize nutrients, are reported in various *Amaranthus* species. All, or perhaps most, of the harmful compounds are leached out in that cooking water.

The young and very tender leaves have the least amounts of these undesirable materials, which is why the plants should be picked early and often. It is also why they should be well watered, fertilized, and generally kept lush and vigorous and freshly formed.

NEXT STEPS

As noted, vegetable amaranth is in a sense invisible to the authorities. Now is the time to open everyone's mind to the crop's promise. The primary monograph on it was published decades ago.[12] That and other books highlighting such tropical vegetables need to be available, widely

[12] Grubben, G.J.H. 1976. *Cultivation of Amaranth as a Tropical Leaf Vegetable*. Department of Agriculture, Royal Tropical Institutes, Amsterdam.

disseminated, and revised, helping researchers engaged in improving global food supplies to pay these plants heed. Indeed, a worldwide collegial partnership to foster greater use of vegetable amaranths is worth mounting.

Horticultural Development Selection and crossbreeding is one area that could bring rapid advances. *Amaranthus* species demonstrate high levels of variability in leaf size, leaf shape, branching, bolting pattern, growth and regrowth ability, and color. Indeed, the vast wide geographical spread of the genus has produced many landraces, and in their present undeveloped state amaranths offer more genetic diversity than do many much better understood crops. The huge gene pool in widely separated areas can be tapped for the future development of the crop. This is an excellent genus as well as an excellent time in history for plant explorers and local plant lovers to get engaged.

One of the least known and least developed species is *Amaranthus thunberghii*, a semi-wild species native to southern Africa. This seems to have exciting potentials and clearly deserves increased attention. It grows very fast and is resistant to water stress. It is also tolerant to many insect pests such as aphids, fall armyworm etc. *A. thunberghii* has a more prostrate growth habit than its relatives, which may or may not be a benefit. It has been classified as an aphid-trap plant, which opens up intriguing possibilities for research endeavors.

Although vegetable amaranths have been neglected, this dereliction is, as we've said, not universal. Asian growers have been making selections by decades. Named varieties suitable for widespread culture are available from seed companies in Hong Kong, Taiwan, the United States, and elsewhere; many can be located on the internet. These "elite" forms are probably the most technologically advanced and most thoroughly developed forms.

Regarding vegetable amaranths, much crop improvement has been done, but more could be accomplished by studies of:

- Pest and disease resistance;
- Nutrient uptake and nutrient content at different stages of growth;
- The yields from clipping versus successive planting;
- Regrowth after harvest ("ratooning") and the best height at which to clip the plant and the best intervals between clippings;
- Seed production and farmer-selection techniques;
- Leaf-to-stem ratio;
- Delayed flowering;
- Planting and cultural practices for efficient use of land, water, and fertilizer; and
- Crop rotation to avoid soil-borne diseases.

Also needing study is the forage use of leafy amaranth. The recent

Chinese experience is especially illustrative of the potentials and the possible means for feeding pigs with "pigweed."

Food Technology Deserving of research and testing are:

- Food quality, including tenderness and storage methods to prolong the life of the harvested produce;
- Leaf color and antinutritional factors. It seems likely that the bright red and purple-leafed types are the least desirable as foods;
- Accumulation of antinutrition factors in response to type and quantity of fertilizers and soil;
- The variation in flavor among varieties;
- Effect on nutrient retention by processing, such as boiling, steaming, or drying (for later availability during the dry season);
- Provitamin A and iron bioavailability;
- Product development;
- Toxicological studies; and
- Nutritional studies, such as supplementation effects.

Actually, some research in these areas has already been conducted and efforts are needed to make the results more widely known and better used.

Vitamin A On the face of it, amaranth leaves could be an important remedy for vitamin-A deficiency, one of the world's horrors that is subject to increasingly intense outside interventions. Many or most of the programs could incorporate vegetable amaranth. Benefits could accrue not only to Africa but to Indonesia (a country notable for this blindness-inducing affliction) and other parts of Asia.

Leaf-Protein Isolates A future promise of vegetable amaranths is the development of leaf-protein concentrates.[13] Compared with most other species, amaranth leaf protein is highly extractable. In one trial, amaranth had the highest level of extractable leaf protein among 24 plant species studied. During the extraction of protein, most other nutrients are extracted as well: for example, provitamin A, polyunsaturated lipids (linoleic acid), and iron. Heating or treating the extract with acid precipitates the nutrients as a leaf-protein concentrate. In the process, most harmful compounds are eliminated, as they remain in the soluble phase. The green cheese-like coagulum is washed with water slightly acidified with dilute acetic acid (vinegar) to reduce further amounts of possible antinutritive factors. The resulting leaf-nutrient concentrate is especially useful for young children and

[13] The pioneering work by Rolf Carlsson (University of Kalmar, Sweden) on the use of amaranth leaf-protein is especially to be noted here.

other persons with particularly high protein, vitamin A, and iron needs. The fibrous pulp left after extracting the amaranth greens is a suitable feed for animals. The protein quality of the amaranth leaf-nutrient concentrate (based amino acid composition, digestibility, and nutritional effectiveness) is excellent. It is, however, species dependent, probably because of the presence of secondary substances.

Special Interest Projects It has been reported that amaranth is highly suitable for incorporation into crop rotations. It is usually unaffected by common soil diseases such as nematodes, fungal, and bacterial wilt.

Recent reports claim that amaranth benefits from intercropping with species such as celosia and/or jute (*Corchorus*). Further confirmation is in order because this could be an exceptionally important finding. Rotations between these rather similar potherbs could be advantageous to nutrition and dietary variety as well as yield.

SPECIES INFORMATION

Botanical Name *Amaranthus* spp.

Family Amaranthaceae

Common Names

Afrikaans: hanekam, kalkoenslurp, misbredie, varkbossie
Congo: bitekuteku (*Amaranthus viridis*, Kinshasa Province)
English: African, Indian, or Chinese spinach, tampala, bledo, pigweed, bush greens, green leaf,
French: calalou, callalou
Spanish: bledo (Central America)
Fulani: boroboro
Ghana: madze, efan, muotsu, swie
Sierra Leone: grins (Creole), hondi (Mende)
Hausa: alayyafu
Temne: ka-bonthin
Philippines: kulitis (Ilongo), uray (Tagalog)
Indonesia: bayam itik, bayam menir (Java), bayam kotok (Sumatra)
Thailand: pak-kom
Nigeria: efo, tete, inene
Jamaica: callaloo
Tswana: imbuya, thepe
Venda: vowa
Xhosa: umfino, umtyuthu, unomdlomboyi
Zulu: imbuya, isheke
Malawi: bonongwe
China: hiyu, hon-toi-moi, yin choy, hin choy, een choy, tsai

India: Ranga sak, ramdana, rajeera, lal sak, lal sag
Malaysia: bayam puteh, bayarn merah
Caribbean: callaloo, calaloo, etc.

Description

Amaranthus species are herbaceous, short-lived annuals. The plants are upright and sparsely branched. The stems are erect, often thick and fleshy, and sometimes grooved. Dwarf forms, about 60 cm high, are best for the small garden. The leaves are normally alternate and are relatively small (5-10 cm long), but the lines grown as vegetables mostly have leaves longer than normal. The leaves show much variability in shape, color (principally green or red, but some varieties are purplish with the pigment betalain). The flowers are small, regular, and unisexual and are borne in abundance in terminal or axillary spikes. The seeds are small, shiny, and black or brown.

Distribution

Within Africa Several species of amaranth are in cultivation but *Amaranthus cruentus* (*A. hybridus*), *A. blitum* and *A. dubius* are the most widely grown in Africa and are particularly important in West Africa.[14] Hybrids between species and varieties exist, some of which have been designated as species or subspecies.

Beyond Africa Several species exist depending on the region in the tropics. For example, *Amaranthus tricolor* is mostly found in East Asia, China, and India (where amaranths are especially ancient and diverse) while *A. caudatus* is common (as a cereal) in the Andean nations of South America and throughout the Himalayas, and *A. dubius* (as a vegetable) in the Caribbean, India and China. *A. hybridus* is grown for grain or vegetable production in the southwestern United States, China, India, Indonesia, Malaysia, Mexico, Thailand, Philippines, Nepal, the Caribbean, and most likely many other places.

Horticultural Varieties

Unlike the crops in other chapters, this one occurs as separate species, including the following:

Amaranthus cruentus L. This grain type has a long stem and bears a large inflorescence. A very deep red, dark-seeded form of the species, sometimes known as blood amaranth, is often sold as an ornamental in commercial seed

[14] The Asian species, *Amaranthus tricolor* (*A. oleraceus*, *A. gangeticus*) , an import from India, is sometimes seen, but rarely.

packets. Like corn, sweet potatoes, peanuts, and other American crops, *Amaranthus cruentus* was evidently introduced to Africa by Europeans. But then it passed quickly from group to gruop outrunning European exploration of the interior, so that Livingstone and others found it already under cultivation when they arrived. The white-seeded form is used as a cereal. The black-seeded version is the one used as a vegetable, and it has probably been used that way in Africa since the 16th or 17th centuries.

Amaranthus dubius Mart. ex Thell. This weedy species is a green vegetable of West Africa and the Caribbean, and is found in Java and other parts of Indonesia as a home garden crop. One of its best varieties, the cultivar 'Klaroen,' is particularly popular in Suriname and has been introduced in Benin and Nigeria. This fast growing, high yielding plant has distinctive dark-green, broad, ridged leaves and is considered very palatable. It is the only known tetraploid (2n=64) in the genus.

Amaranthus hybridus L.[15] One of the world's most common leafy vegetables, this weedy herb originated in tropical America, but is now spread throughout the tropics and is a frequent component of kitchen gardens. It also grows wild on moist ground, in waste places, or along roadsides. The plant is fast growing, requires little cultivation, is resistant to moisture stress and produces a good yield of grain in sorghum-like heads. The size and color vary greatly. Red-stemmed varieties are usually planted as ornamentals; green varieties are the ones employed as vegetables.

Amaranthus blitum L. This widely distributed species (also known as *A. lividus*) is well adapted to temperate climates and has a number of weedy forms that come with either red or green leaves. It promises to allow the development of highly palatable crossbred vegetable amaranths. In Madhya Pradesh, India, the edible forms, known as norpa, are especially liked for their tender stems. This species is widely eaten in Greece under the name vleeta. It is also grown in Taiwan, where it is known as horsetooth amaranth. A widespread weed of waste and cultivated ground, it is commonly eaten in many parts of Africa. The leaves are soft and the cooked product is sweet tasting and much liked.

Amaranthus tricolor L. Varieties of this species are native to a large area from India to the Pacific islands and as far north as China. It is probably the best-developed vegetable amaranth: the plants are succulent, low growing, and compact, with growth habits much like spinach. They are produced as a hot-season leafy vegetable in arid regions when few other leafy greens are

[15] The exact relation between this species and *Amaranthus cruentus* is in dispute. The two may be wild and cultivated forms of the same species or they may be species apart.

available. In India, a large number of cultivars are available, especially in Andhra Pradesh, Karnataka, Tamil Nadu, and Kerala. Some ornamentals with very beautiful foliage also belong to this species. There are many cultivars in Southeast Asia classified according to leaf color and shape.

Environmental Requirements

Vegetable amaranths need a long warm growing season, and are suited only to the warm-temperate and hotter zones of the earth. If grown in cooler climates they tend to be tough and poor in quality.

Rainfall The crop thrives in areas receiving 3,000 mm of annual rainfall. As it is mostly grown in small plots beside the house, it is frequently watered by hand. Without irrigation it needs an average of at least 8 mm per day of rainfall during its whole season.

Altitude Areas with elevations below 800m are said to be most suitable for cultivation, but the crop can be grown in higher areas. *Amaranthus cruentus*, for example, thrives in altitudes up to 2,000 m.

Low Temperature All species are very sensitive to cold weather. Plant growth ceases altogether at about 8°C.

High Temperature Most species are tolerant of high temperatures and thrive within a temperature range of 22-40°C. The plants establish best when soil temperatures exceed 15°C. Optimum germination temperature varies between 16°C and 35°C.

Soil Although most amaranths tolerate a wide range of substrates, a light, sandy, well-drained, and fertile loam is desirable. Soils with a high organic content and with adequate nutrient reserves produce the best yields. Optimum pH range is 5.5-7.5 but some cultivars tolerate more alkaline conditions.

2

BAMBARA BEAN

In recent centuries the once-obscure peanut has expanded so dramatically as to become one of the world's top crops. Of particular importance to Africa, the peanut (there mostly known as groundnut) contributes substantial nutrition to roughly three-dozen nations encompassing two vast belts, one stretching from Senegal to the Central African Republic and the other from Sudan to South Africa. Indeed, considered in continental perspective, peanut is among the largest African food providers—probably coming right after maize, cassava, and sorghum.

What is surprising is that peanut is a Brazilian native that reached Africa's shores only 400 years ago. And what is even more surprising is that Africa possesses its own counterpart. This local version is similar in virtually every aspect—botanical, agronomic, nutritional, and culinary. Yet while the exotic crop soars to ever-greater heights its stay-at-home cousin languishes almost unknown to agricultural science, food science, economic development, and the world at large.

This African species (*Vigna subterranea*) is a low-growing legume, not unlike its famous relative in appearance. Often called bambara groundnut, it is conventionally classified a bean, but its seeds are actually dug from the ground like peanuts. To outsiders, only the shape seems unusual: the pods are larger and rounder than peanut shells and the seeds inside are shaped more like peas than peanuts. Those spherical legumes are, however, exceptionally tasty and nutritious. They are also attractive—appearing in varying colors and patterns, characterized by pretty local names such as *dove eyes*, *nightjar*, and *butterfly*.

Like peanut, these native ground beans make a versatile food. Most are boiled in their shells and are offered for sale, ready cooked, on roadsides and in markets. Others are pounded into flour and used in making porridge. Some are boiled with maize meal and used in a relish. A few are also roasted or fried. The flour from the roasted version is especially appetizing and is blended into many traditional dishes.

Although overlooked by the world at large, this is an important resource. Burkina Faso provides a picture of the crop in microcosm. All regions of the

Bambara bean is a low-cost, dependable farm resource that grows in harsh environments where many other crops fail. Production is primarily at subsistence level, and only the surplus is sold. For Africa, the crop offers various benefits, being an ideal subsistence crop, a good rotation crop, a good backstop for hungry times, and a promising commercial resource. (Klaus Fleissner)

country grow bambara bean, producing around 20,000 tons in total.[1] Cultivation is exclusively using traditional methods and traditional landraces. Some farmers intersperse the plant among other crops but most grow it in mini-monoculture. Much of the harvest is consumed by the farm family, for whom it is a major source of protein and a lifesaver during the hungry season—the period before the new crops are ready to harvest and the old have been eaten. Beyond this fundamental subsistence use, however, bambara is also a cash crop. Popular with the general public, the fresh beans sell for a premium. There's never a problem peddling any surplus, and the local sales can constitute the grower's overall annual cash income.

The question is why does such a valued resource remain largely unknown to agricultural science, food science, humanitarian programs, and economic development policies?

Clearly, the neglect is no reflection of the user's views. Despite peanut's spectacular surge, its African counterpart remains a consumer favorite. Indeed, even without the help of science sales are actually edging upward. Today, probably more than 100 million Africans routinely rely on this age-

[1] This makes it Burkina Faso's third largest grain legume, after peanut (160,000 tons) and cowpea (74,000 tons). Kiwallo, L. 1991. Inventaire des maladies cryptogamiques du voandzou (*Vigna subterranea* (L.) Verdc.) au Burkina Faso. *Mémoire de fin d'études en agronomie*. Institut du Développement Rural, Université de Ouagadougou, Burkina Faso.

old resource for at least part of their sustenance during each year. Overall production is around 330,000 tons, about half of which is grown in West Africa; the rest in eastern and southern Africa.[2]

Clearly, too, the intellectual inattention is not due to any agronomic inferiority. Bambara bean is a dependable food producer, tolerating harsh conditions and growing reliably in challenging locales, including some where other species fail. It is also among the easier legumes to grow: burying its fruits in the soil, it keeps them safe from the myriad flying insects that can devastate or destroy cowpea, common bean, soybean, and other legumes that heedlessly wave their tastiest parts in the air.

Nor is the disregard due to site restrictions. Other than requiring open sunlight and light, loose soil within which to bury its beans, bambara tolerates widely dissimilar substrates, including infertile ones. Indeed, some observers swear it "prefers worn-out soils."[3] Furthermore, this leguminous species fixes nitrogen from the air, thereby insulating itself from Africa's all-too-common paucity of soil-nitrogen. And beyond all that, the plant thrives in laterite, the reddish acidic soil that is toxic to many crops and is the curse of tropical agriculture.[4]

Doubts about nutritional performance are not the cause of the neglect either. Ripe or immature, raw or roasted, the seeds pack a load of nutrients. On average, they contain about 60 percent carbohydrate, 20 percent protein, 6 percent oil, and a range of vitamins and minerals. This makes them more like a bean than a peanut. A true quality-protein food, they provide more methionine than other grain legumes, let alone the standard staple cereals.

Despite all these benefits, bambara bean has never been accorded a research program commensurate with its importance or potential. Indeed, it has probably received less than a ten-thousandth the technical support the peanut enjoys worldwide. The neglect is only partly because the plant is stigmatized as a "poor person's crop". Rather, it seems largely due to lack of familiarity by those setting the research agenda, especially research donors and agricultural scientists outside Africa.[5]

Now is the time to open minds and award this native resource a greater chance to catch up with peanut. Given technical support, this resource

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[2] Linnemann, A.R. 1994. Photothermal regulation of phenological development and growth in bambara groundnut (*Vigna subterranea* (L.) Verdc.). PhD Thesis, Wageningen Agricultural University, The Netherlands, and Kiwallo, op. cit.

[3] Their observation probably reflects the fact that stress typically stimulates plants to set more seed.

[4] Information from J. Ehlers.

[5] Such institutional inertia can be energized by initiatives such as "BamNet," the International Bambara Groundnut Network founded in Zimbabwe in 1995. Composed mainly of researchers, mostly in Africa, BamNet hopes to improve productivity, marketing, and consumption by sharing experiences. Coordination is done largely through the Internet. Such home-grown initiatives—often driven by just a few committed individuals—make a world of difference in securing the future for these plants.

certainly can contribute vastly more than it does today. Indeed, the plant has the potential to cut to the heart of Africa's great humanitarian problems. Consider the following:

Rural development In the lives of the rural poor this low-cost crop is especially important. Many desperate farm families grow it for their own subsistence and also for their annual income. Thus any boost in output or reduction in production costs will disproportionately benefit the group most at risk. Also, commercial food processing is likely to open up buoyant new market outlets. In this regard, it is notable that the canned product seems to have high marketing potential, especially in urban areas. A Zimbabwean company already cans bambara bean, and reports that (except for "baked beans") it sells as well as any other canned bean—nearly 50,000 cans a year, with sales increasing month after month. Across Africa there is room for many such enterprises, and they will create major markets for farmers and boost income opportunities for rural areas.

Hunger For most of the drier regions bambara bean could contribute to a solid foundation diet. Resilient and reliable, it commonly yields food from sites too hot and too dry for peanuts, maize, or even sorghum. And it produces a food of exceptional nutritional quality, so a little of it goes a long way toward maintaining health.

Malnutrition Compared with peanut, bambara may have a lot less oil and a little less protein, but more carbohydrate and the overall combination nicely balances the food groups. People can live on bambara bean alone, a doubtful proposition even with other legumes. A rare example of a complete food, it could prove a tool for attacking Africa's chronic malnutrition.

Gender Inequality This bean is mostly produced by women, sold by women, and cooked and served by women. It therefore offers a convenient lever for lifting women up to a better existence. Improve this resource and you improve the lives of millions of mothers, not to mention babies born and unborn. In a related vein, bambara bean offers good opportunities for gender-oriented innovation and commercial development. In the Bida region in central Nigeria, for instance, women make pancakes from the flour and reportedly enjoy a good living selling them. Also in Mali women sell salted bambara nuts, a premium product similar to macadamia nuts and suitable for urban areas and possibly for export as well.

Food Security For much of Africa unpredictable drought is the biggest fear, and this crop might prove an ideal insulator against this periodic shock. Wherever rainfall is unreliable it tends to shine. Bambaras—the people for whom it is named—live in parched, blisteringly hot districts along the

Most seeds pods are picked while still soft and immature; the seeds are eaten fresh or roasted. With a calorific value equal to a quality cereal, this pulse is suitable for use as a staple. As with chickpea and lentil, this legume sustains life. (Werner Schenkel)

Sahara's southern fringe, and their namesake plant lives up to its etymological heritage.

Sustainable Agriculture Bambara bean epitomizes the current ideal of a "sustainable crop." Every plot is a mixture of genetic diversity and no plant is fertilized or sprayed. In addition, the species' nitrogen-fixing capacity helps boost soil fertility, naturally. It can even be used as a soil conditioner. Programs aiming at achieving sustainable farming in Africa could find no better foundation upon which to build their efforts.

Trade Deficits Countries along the southern Sahara have long shipped bambara beans to markets on the Gulf of Guinea coast. Niger is the principal exporter, followed by Chad, Burkina Faso, Mali, and Senegal. Those happen to be among the nations most needful of foreign exchange, and enhancing this particular trade could be part of the answer. Reportedly, the coastal areas have a still unmet demand.[6] A similar situation apparently exists in

[6] This is according to a study issued by the International Trade Centre in Geneva, among others.

southern Africa as well. Although Zimbabwe has exported thousands of tons of the dried beans to its neighbors, there is believed to be openings for more.

In sum, bambara bean promises sweeping benefits to the people most in need and hardest to reach through conventional development programs. And despite the almost total scientific neglect, nothing fundamental is stopping this crop from moving on to greater heights.

Of course, technical difficulties deserve attention (as they do with corn and soybean and all crops). These are treated later in the chapter, but it is worth highlighting one example: low yield. Average farm production is now around 400 kg per hectare, yet under improved conditions the crop produces over 4,000 kg per hectare. Farmers today, therefore, achieve merely a tenth of what they could. Clearly, the opportunities for improvement are huge. And the results would be staggering indeed if, in rural areas of hard-pressed countries such as Burkina Faso, ten times more bambara beans could be produced. The effects would in fact be revolutionary.

PROSPECTS

Empirical evidence and preliminary investigations suggest that with attention, bambara could rise to prominence within just the next 20 years. From today's perspective, that might seem farfetched, but peanut's stellar performance shows how quickly a newly appreciated resource can ascend.[7]

Within Africa

Due to its relative resistance to diseases and pests, bambara bean has the potential to improve food security in many rural areas as well as become a stable, low-cost and profitable food crop for Africa's small-scale farmers. Given the support of good science, conducive government policy, bold investment by food processors, and dedicated local initiative, it could soon be reducing malnutrition and raising both economic levels and human well being.

Humid areas Good. Although details remain sketchy, the plant is capable of growing in rainy areas. However, dampness brings out fungal diseases and means that the plant needs careful handling. Also, the harvest must be made promptly—before the tops have signaled their readiness by turning

[7] Researchers for the FAO, taking bambara as an example of an "underutilized crop," used weather, soil, and other data to model its potential for growing across Africa and the globe. Their predictions show it widely adaptable to much of the area of peanut and beyond, especially the Mediterranean rim. Azam-Ali, S., J. Aguilar-Manjarrez, and M. Bannayan-Avval. 2001. *A Global Mapping System for Bambara Groundnut Production.* FAO Agricultural Information Management Series No. 1. FAO, Rome; available online via www.fao.org/documents/.

yellow. And special provisions are needed to dry the seeds and store them safely.

Dry Areas Excellent. Bambara bean is one of Africa's most drought-tolerant native legume food crops.

Upland Areas Good. The crop does well in the highlands of Zambia and Zimbabwe. At Gwebi in Zimbabwe, for example, yields of 4,000 kg per hectare have been realized.[8]

Beyond Africa

Bambara bean is cultivated in Brazil (under the name *mandubi d'Angola*) as well as in at least two parts of Asia: West Java and southern Thailand. In principle other tropical locations could grow it too. It is said that the crop could produce in the Middle East. FAO studies claim that both Syria and Greece are suitable. Small-scale cultivation trials have been successful in United States, notably in Florida, but no one has yet tried moving it into general production.

USES

Like most legumes bambara bean is used in a variety of ways.

Home Uses As mentioned, in many African countries the pods are boiled and the seeds consumed as snacks. This seems to be the most widespread use. However, in East Africa, the beans are roasted, pulverized, and used as a base for soups that can be either bland or made zesty with added chilies.

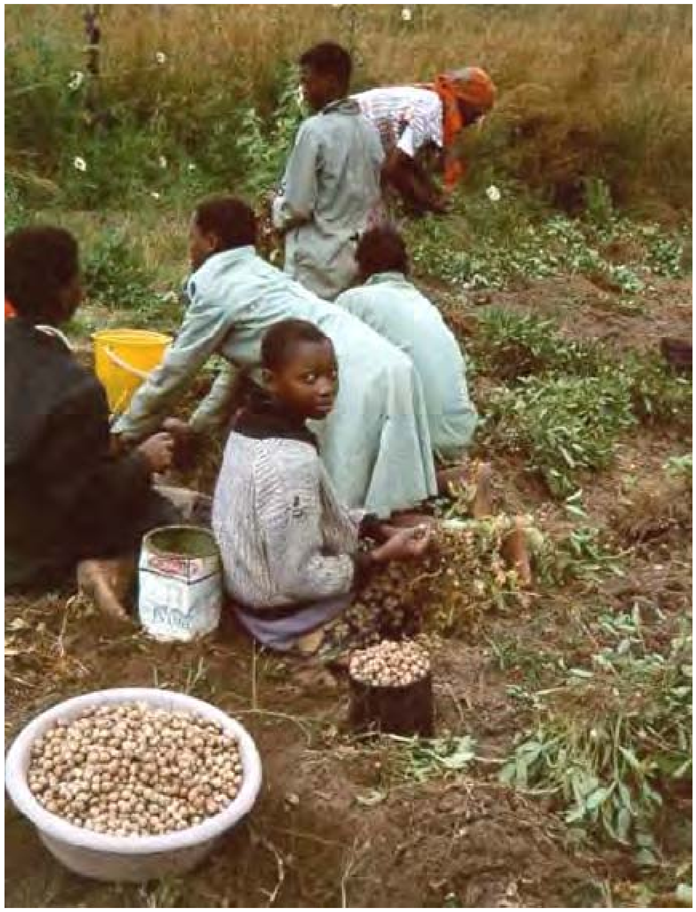
Processed Foods Any seeds that reach full maturity turn hard and indigestible, and require boiling and/or grinding into flour to become edible. Such flour is commonly used to thicken and flavor cereal products. In Zambia, it is also made into bread. In Zimbabwe, as we've said, bambara bean is canned.[9]

Another common practice is to crush the dried seeds into a paste. Various fried or steamed products made from this are very popular in Nigeria and neighboring nations. One, called *akara*,[10] is a form of bean fritter that is frequently sold on the street and is especially common at bus stations.

[8] This was at the research station, at about 1,500 m above sea level. Information from D. Greenberg.

[9] Zimbabwe was not the first. In Ghana, a government factory at Nsawam (just north of Accra) canned bambara groundnuts in gravy and for years sold well over 40,000 cans annually. Sadly, when privatized the company dropped this part of the business.

[10] Other names include *accra*, *akla*, *binch akara*, *kosai*, *koosé*, *kwasi*, or bean balls. It is also prepared at home for breakfast, snacks, or side dishes at dinner.



Manzini region, Swaziland. The family of Mrs. Fakudze (at back wearing headscarf) helps harvest the bambara crop. Like peanut, the plant forms pods and seeds underground. Unlike peanuts, the seeds are round, smooth, and very hard when dried. Among the most adaptable of all crops, it tolerates harsh conditions and yields food in droughty sites where peanuts, maize, or sorghum fail. (Karen Hampson)

Another, called *moin-moin*, is a sort of savory bean pudding. Yet a third, *okpa*, is a doughy paste that is wrapped in banana leaves and boiled. These age-old favorite “fast-foods” are mainly made with other beans, but those made from bambara are considered the best.

Oilseed With an oil content of only around 6 percent, bambara bean would seem to make for an unlikely oilseed, but reportedly some peoples in Congo pound the roasted nuts and separate the liquid for cooking.

Animal Feed Bambara beans have been fed to chicks with great success. The leaves, which are rich in protein and phosphorus, make useful livestock fodder. The haulm (stems, leaves, and other crop residues) is palatable, rich in nitrogen and phosphorus, and is also highly suitable for grazing animals.

Medicinal Use Among beans this one is said to have the highest concentration of soluble fiber, a non-nutrient famously occurring in oatbran and believed to reduce the incidence of heart disease and to help prevent colon cancer.[11] In addition, the crop has medicinal uses in many areas in Africa. In Botswana, for example, the black seeded landraces have the reputation of being a treatment for impotence.

Other Uses By contributing nitrogen to the soil the living plant is a good companion in crop rotations.

NUTRITION

Ripe or immature, the seed averages 63 percent carbohydrate, 19 percent protein, and 6.5 percent oil.[12] The protein, as formerly noted, contains more of the nutritionally essential amino acid methionine than that in other beans, making it more complete.

The seed has the reputation of being very filling. And no wonder: its nutritional energy (per 100g) has been measured at 367-414 calories, an amount greater than that of common pulses such as cowpea, lentil, and pigeon pea.[13]

Although formal infant-feeding studies are unreported, a trial has been conducted of "milks" prepared from bambara bean, cowpea, pigeon pea, and soybean.[14] Whereas all were declared acceptable, the scientists ranked bambara-milk first in flavor, nutritional value, and color. The mothers and (seemingly) their babies preferred it too.

HORTICULTURE

The plant comes in two basic shapes: a sprawling, ground-hugging type and a more upright, "bunched" or bush type that stands erect. The former is grown exclusively by smallholders as a subsistence crop; the latter is the one planted in larger-scale farming. Because there are no formal varieties, all

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[11] Information from D. Greenberg.

[12] The ranges of these ingredients are carbohydrate, 55-72 percent; protein, 17-25 percent; and oil, 5-8 percent.

[13] FAO. 1982. *Legumes in human nutrition*. FAO Food and Nutrition Paper No. 20. FAO, Rome.

[14] Brough, S.H., S.N. Azam-Ali, and A.J. Taylor. 1993. The potential of bambara groundnut (*Vigna subterranea*) in vegetable milk production and basic protein functionality systems. *Food Chem*. 47:277-283.

plantings involve mixtures of landraces selected during traditional production.

So far, there are no standard methods for handling the crop. Speaking generally, it is produced like peanut. Most farmers sow early in the rainy season, usually dropping two to four seeds into a hole about 5 cm deep, and covering them with soil. Planting density is normally low, especially when the planting is not organized in rows. The literature gives the optimal spacing as anything from 40x25 cm to 60x60 cm. Given the mixture of seeds emergence is necessarily variable, extending from 7 to 21 days.

The crop is most often sown in the family's main field (rather than its kitchen garden), frequently being tucked into the corner of the maize or sorghum plot. Some farmers use ridges or mounds. As with peanut, they "hill up" the plants.

Soil is the key to success: It must be loose and loamy enough for the pegs to penetrate. Those fragile flower stems emerge from the base of the pealike yellow blooms, elongating until they meet the soil below. Once they've pushed below the surface, the tips swell and the seeds begin forming. As the seeds mature below ground, the aboveground parts gradually lose their vivid-green vitality and turn yellow, a signal that the seeds are ripe for digging.

Given that fertilizer is uncommon in Africa, this crop's requirements are unrecorded. In West Java, the one place where farmer practice has been detailed, urea is sometimes sprinkled around the young plants. In southern Thailand, where soil fertility is quite low, any available fertilizer is applied as a side dressing along the rows at rates up to 150-300 kg per hectare.

HARVESTING AND HANDLING

Like peanut, bambara bean develops slowly. Depending on climate and cultivar it may take anything from 90 to 180 days to mature. Most of today's main types are ready to harvest in 130-150 days, or about 2 months after the pods first appeared.

In the dry zones, the timing of the harvest is less critical than with peanuts; bambara beans can be gathered early or late without serious loss. However, if they are to be used as snack, they must be harvested just before the leaves begin yellowing. And in humid areas prompt harvest becomes vital because seeds left in the warm damp soil can rot or germinate.

To harvest the crop, the whole plant is pulled up. With the bunched-type, most pods remain attached to the root crown. The per-hectare yield is generally 300-600 kg of dried seed. As we've said, much better production is possible: Six independent trials in several Central African countries recorded yields in excess of 2,000 kg of shelled seeds per hectare.[15] A 1969 report from Ukiriguru Experiment Station in Tanzania recorded yields up to

[15] Johnson, D.T. 1968. The bambara groundnut: a review. *Rhodesia Agric. J.* 65:1-4.

2,600 kg per hectare. Various other documents refer to experimental yields in excess of 3,000 kg per hectare. And in West Java yields of 5,000-6,000 kg per hectare are recorded.

Freshly harvested pods are typically left in the sun several days, during which time they shrink, darken, and dry out. After threshing to separate the vegetable matter, the harvest is marketed either as pods or as seeds.

In storage, shelled bambara beans are susceptible to bruchid beetle. The pods, however, are extremely resistant. Farmers therefore keep their seeds for planting in the unshelled form.

LIMITATIONS

On the agronomic front, the lack of varieties with stable and predictable yield is the main concern. Formal attempts at breeding have so far been unsuccessful. Every planting therefore now employs landrace mixtures, and plants in a single field differ wildly in appearance, performance, and product.

A point that has only recently been recognized is that the crop—or at least some of its types—is photosensitive.[16] This could explain why some cultivars mature exceptionally late. Photosensitivity can be a two-edged sword. On the positive side, it can ensure that certain types mature at exactly the right time (usually the end of the rains) for a given location. On the negative side, it can restrict the seeds to that same location and to a single planting time each year.

The plant nodulates freely. Specific *Rhizobium* strains can boost its growth far above normal (with average strains), but as of now those select strains are poorly characterized and the farmers are not benefiting much from them.

Despite its general robustness, this plant can fall victim to fungal disease (notably fusarium wilt and leaf spot). Usually this occurs only when and where the conditions are unusually damp. On the other hand, viral diseases are widespread across many environments, especially where cowpea and other grain legumes are grown.[17] Also, even when hidden below ground the seeds are not entirely beyond danger: Rodents, crickets, and (in especially dry weather) termites can be problematic. In sandy soils nematode infestations can be bad.[18]

The pegs seldom penetrate far, which is why the farmers "hill" soil over them. Any that stay exposed to sunlight tend to turn green and to develop improperly.

The crop has potential for large-scale production, but under the rigors of

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[16] Linnemann, op.cit.

[17] Common are cowpea mottle virus and cowpea aphid-borne mosaic virus.

[18] In Botswana, for example, farmers who lack the land to rotate their crops are reporting heavy losses. Information from S.K. Karikari.

mechanical harvesting the current types tend to "shatter" (drop their pods). A related problem is the lack of a mechanical sheller.[19]

Although genetic diversity can be a selling point and perhaps an insurance policy, it hinders large-scale operations. Because of its diversity, for instance, bambara bean cannot be processed using a consistent formula and some consumers are put off. When you get right down to it, a bean of variable texture and taste has difficulty competing with the super-consistent Michigan pea bean, for example, all of which are identical in size, color, taste, and texture.

One serious limitation is the time needed to cook the dry seeds. Wherever firewood is scarce, this can pose a problem.

The seeds reportedly contain "flatus factors," which like their counterparts in common beans reduce, but don't eliminate, the food's desirability. A good 24-hour soak is said to reduce the effect.

NEXT STEPS

With a crop as neglected as this, almost everything needs doing. Following is a selection.[20]

Building a Bigger Market We are confident enough of the bambara bean's basic qualities to recommend that the first focus be the output end. Opening up opportunities for sales will produce an explosion of grower interest and almost automatically result in greater planting, greater research, and greater recognition all round. Opportunities for increased sales could be in the formal and informal sectors, urban centers, rural centers, exports, and commercial food processing. For farmers the key issue will be price. If they can achieve the same returns they get for other premium beans, this crop will emerge from hiding all across the continent.

The key to higher prices is strengthened demand. And marketing campaigns are one way to strengthen demand. This commodity above all else needs publicity. Even in tropical Africa, millions remain unaware of its existence, let alone its benefits. The information should be aimed especially at urban areas and the younger generation. It should be a typical consumer-awareness venture (not excluding endorsements by local celebrities). Adjuncts in this case might include recipes in various local languages and special dishes served in fancy restaurants and state dinners.

Processing can also help break through mental barriers. According to one

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[19] In this regard, a mechanized bambara-groundnut sheller is reportedly under development in South Africa.

[20] Other research ideas and a comprehensive review of this crop, including bibliography, can be found in Heller, J., F. Begemann, and J. Mushonga, eds. 1997. *Bambara groundnut:* Vigna subterranea *(L.) Verdc.* International Plant Genetic Resources Institute, Rome; available online via www.ipgri.cgiar.org/publications.

reviewer, Zimbabweans formerly viewed bambara bean as a famine food, fit for eating only as a last resort. However, when it became available in cans all that changed. Suddenly, it was seen as modern.

Any publicity campaign might be extended internationally. To consumers in North America or Europe canned bambara bean will look much like other canned beans. But it will take on a new mystique once they know that: 1) it was grown by impoverished women farmers, 2) it was grown organically, and 3) every purchase helps preserve an ancient heritage of biodiversity. The future could perhaps see a movement not unlike those aimed towards fostering shade-grown coffee or rainforest candies.

International food-relief agencies could help as well. Using local bambara instead of importing foreign beans would stimulate farmer interest, consumer confidence, and overall production.

In a related vein, the publicity programs should aim at broadening the crop's uses. In eastern and southern Africa, for instance, it is currently viewed as a snack food. Extending its use to include the main-course dishes will see hundreds of thousands of small farmers substantially increase production, profits, and prospects.

In modifying people's mindsets, it is important to develop better figures on the present production. One of our reviewers urges that governments stop burying bambara bean under "Other Pulses," and include it separately in their national agricultural statistics. This will, he says, enhance the crop's reputation and status in policymaking and development programs.

On-Farm Promotion Parallel to the public-awareness promotions, there needs to be farmer-awareness activities. Currently, many farmers don't plant bambara bean solely through lack of knowledge, confidence, or advice. In parts of its range, the limit is merely a lack of quality seed. Governments and seed suppliers should rectify this by multiplying whatever reasonable landraces are on hand. Also, extension agents should encourage farmers to set aside areas for producing bambara-bean seed for themselves and their neighbors. Although NGOs, commercial organizations, and extension services should assist in seed multiplication, farmer-to-farmer exchange programs could prove especially good mechanisms for upgrading this crop.

Genetic Resources and Breeding The genetic diversity needed to improve bambara bean is already on hand. Collections have been made across Africa, and the resulting seeds remain securely stored in facilities across Africa.[21] Therefore, in the long process of improving this crop, one

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[21] The largest collection is held by IITA in Nigeria while a smaller collection is held at the Crop Research Institute in Ghana, along with several other locations in Africa. The collections differ markedly in general morphology, particularly size and color of seeds, number of pods per plant, and color of leaves. Specialists have declared that the existing germplasm collections hold insufficient population samples from Chad, Ethiopia, Niger,

starting point is this germplasm. Having come from different parts of the continent these seeds should demonstrate the genetic treasures within this species. Then, through judicious selection and breeding, the road to cultivars possessing broad adaptation to Africa's various environments ought to open up.

The plant's underground flowers make cross-pollination difficult, but attempts are nonetheless being made to breed in desirable characters, particularly high and stable yield, early maturation, and photo-insensitivity. These are important actions, but more are still needed to ensure that the crop moves forward with a broad-based and reliable genetic underpinning. They plants are self-compatible and largely self-pollinated (though ants may help increase pollination levels), so once a variety is found it should stay reasonably stable.

In part, parallel crop breeding activities are necessary because bambara bean occurs throughout Africa and occupies a vast array of different sites. Though this suggests a highly adaptable plant, there are indications that individual cultivars are site-specific. Tanzanian cultivars, for example, have yielded poorly in Zambia. Indeed, some from northwestern Tanzania failed in the drier climes and different soils of central Tanzania. For starters, the most effective research on improving this crop may be to concentrate on local landraces.

However, it is also important to separately sort out the photoperiod effects, and to create day-neutral types that will grow in different latitudes and seasons. Shuttle breeding could be the key to long-term success, as it was with the wheats that created the Green Revolution in Asian and Latin America. Moving seeds sequentially from location to location and discarding all but the best producers at each site quickly distinguishes the most resilient and adaptable types.

In part, too, parallel crop breeding activities are needed to produce different plants for different farming styles. Types suitable for large-scale mechanized farming are needed on the one hand, and types for small-scale cultivation by subsistence farmers on the other. It has been suggested that the targets be: a bunch ideotype for large-scale mechanized farming and a spreading ideotype for smallholders dependent on cereal-based subsistence systems where the plants are more scattered.

Although we've noted that adequate genetic diversity is on hand, more collections are needed on farms in Burkina Faso, Togo, and Nigeria's middle belt—a zone thought to include the greatest variation. Further, there is a need to collect the ancestral, pre-domestication wild form that is distributed in natural areas from Jos Plateau and Yola in Nigeria, to Garoua in Cameroon, and probably beyond.

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and Sudan. Begemann, F. 1988. *Ecogeographic Differentiation of Bambara Groundnut (*Vigna subterranea*) in the Collection of the International Institute of Tropical Agriculture (IITA)*. Wissenschaftlicher Fachverlag Dr Fleck, Niederkleen, Germany.

Horticultural Development Given the almost complete lack of tested information, the crop's agronomy deserves intensive study. This doesn't, however, demand a delay for research investigations: enough expertise already exists to raise the crop's productivity many-fold and quickly.

Part of that expertise is stored in the minds of Africa's farmers, and there is a need to assess their practices and adapt the best Africa-wide. On the other hand, part of that expertise is stored in the minds and manuscripts of peanut researchers who have no inkling their crop has an African cousin, let alone that their experience could help it. Peanut research is prominent in the United States, Brazil, Australia, and several African nations. Researchers there should include exploratory studies with the bambara bean. In this way, they will likely see how to quickly lift levels of production and utilization. As a bonus, they might reap powerful insights into the peanut plant.

In particular, the crop's management on a larger scale needs advancement. Investigations of mechanized cultivation and harvesting, and the overall adaptation of modern peanut-farming methods should be undertaken. Investigations into mechanized shelling and processing (especially canning) are more than justified. A machine to crack open pods could do more than almost anything to advance thie crop.

Although bambara bean is relatively free of pathogens and pests, research to identify cultivars more resistant to the major known threats could be most helpful. Trials should be made in ecological zones rife with the particular disease or pest. It is there that the plant's ultimate adaptability and resistance can best be determined.

Unconfirmed observations indicate that the crop can suppress striga, a parasitic weed particularly prevalent in Africa's sandy soils. In addition, as we've noted, the plant is said to thrive in laterite, the reddish acidic soil that is rich in soluble aluminum and toxic to many crops. And the crop reportedly does very well in sandy soils. Each of these capabilities deserves rapid assessment and promotion because each would be great value to Africa, just by itself.

Nutrition and Food Technology Nutritionists and food technologists—whether inside Africa or not—should pay close attention to this overlooked food plant. Huge gaps in the knowledge base still remain to be bridged.

For one thing, the micronutrients—both vitamins and minerals—need careful documentation.

For another, the overall digestibility needs checking. Antinutritive factors are likely to be present, and their levels during different stages of seed maturity need assessment. In addition, their fate during various types of cooking should be followed. Finally, their levels in different seed types need measuring.

For a third, aflatoxin levels should be assessed on bambara bean samples.

Given this cancer-causing chemical's threat to the safety of peanut, this would be a wise precaution.

Beyond those fundamentals, this food needs testing in programs engaged in fighting malnutrition. At least one researcher has suggested it could form the basis for special dietetic foods for children. In as much as the crop grows in some of the most malnourished nations, this should be followed up. Interesting in this regard would be head-to-head comparisons with soyfood counterparts.

As we've noted, the crop could find use in food industry. Processing methods such as canning, milling, popping, puffing, and protein extraction might lift it into many new markets. Snack foods are a special possibility. Possibilities for such processed foods in world trade should be considered.[22]

For such large-scale operations, the option of packaging boiled beans in pouches should be considered, as it might avoid the expense of metal cans. Solar heating and storage under anaerobic conditions (e.g. in sealed metal drums or plastic bags) could be effective ways to reduce post-harvest losses.

As noted, too, at least some seeds contain flatus factors. The levels of poorly digested sugars should be checked in a range of different strains. It's possibly a long shot, but it might lead to breeding lines with elevated digestibility and greater consumer acceptance.

The fact that the seeds are rich in soluble fiber deserves follow up. Other crops containing such substances are widely touted to reduce the incidence of heart disease and help prevent colon cancer. Psyllium and oats have turned into major international resources solely on the basis of possessing this same non-nutritious nutrient. Might a new bambara bean export line be developed around it too?

SPECIES INFORMATION

Botanical Name *Vigna subterranea* (L.) Verdc.

Synonyms *Voandzeia subterranea* (L.) Thouars.

Family Leguminosae Subfamily: Papilionoideae

Common Names

Afrikaans: dopboontjie
Arabic: gertere, guerte
English: bambaranut, bambara groundnut, Congo goober, earth pea, baffin pea, Njugo bean (South Africa), Madagascar groundnut, ground bean, earth bean, earth nut
French: voandzou, pois d'Angole, haricot pistache, pois arachide, pois

[22] This is not as farfetched as it may seem. The Zimbabwe company already mentioned filled an order from a food processor in California for a container of the dried beans.

Bambarra, pois Souterrain, vanzon,
Portuguese: mandubi d'Angola (Brazil)
Sierra Leone: agbaroro (in Creole)
Ghana: aboboi, akyii
Nigeria: epi roro, guijiya, gujuya, okboli ede
Hausa: juijiya
Ibo: okpa otuanya
Yoruba: epi roui
Sudan: ful abungawi
Central Africa: njogo bean
Kenya: njugu mawe
Zambia: juga bean, ntoyo
Malawi: nzama, njama
Zimbabwe: nlubu, nyimo, jugo bean
Madagascar: pistache Malagache, voanjobory
Ndebele: indlubu, ditloo
Shona: nyimo
Swahili: njugu, njugu mawe
Tsonga: kochane, nyume, ndlowu
Venda: nduhu, nwa, tzidzimba
Xhosa: jugo
Zulu: indlubu
siSwati (Swaziland): tindlubu
Indonesia: kachang Bogor,
Thailand: thua rang
Malaysia: kachang Manila (Manila bean), kachang tanah, nela-dakalai
Surinam: gobbe

Description

The plant is a herbaceous annual, often spreading or trailing, but also erect and bushy. It has a well-developed taproot with profuse geotropic lateral roots. New roots often appear where nodes contact soil. The fibrous lateral roots form nodules for nitrogen fixation. In association with appropriate rhizobia they usually nodulate well.

The stems are branched and hairy, with short internodes. The leaves are trifoliate and are borne on long slender petioles. The flowers spread out close to ground level on hairy peduncles, each producing one to three flowers. Most flowers are light yellow in color, although some are deep yellow (especially late in the day). After pollination, each small flower sends down a tendril, or peg, like a long root, which continues to burrow even after it has pierced the soil.

Like peanut, the plant then forms pods on, or just beneath, the ground. The pod achieves its mature size about 30 days after fertilization. The seed further develops in the subsequent 10 days. Most varieties have single-

BAMBARA BEAN BEYOND AFRICA

Bambara bean was known in Brazil as early as the 1600s, and its origin is clear from its name: *mandubi d'Angola*. Portuguese voyagers—most likely slavers—carried it across the Atlantic. Many crops were carried both ways between Brazil and today's Angola, Mozambique, Guinea-Bissau, Principe and Sao Tome. Indeed, from those germplasm swaps Africa received peanut, cassava, and maize—the three main foods that now feed the continent.

By a historical accident, the first botanical mention of the crop was by Marcgrav de Liebstad, who recorded it as a native Brazilian crop in 1648. Then for another 158 years the crop was lost to the literature. It was only in 1806 that another botanist (Du Petit-Thouars) stumbled across the same species growing in Madagascar, under the name *voanjo*. Following that rediscovery, it took about another century of botanical sleuthing to finally confirm that the plant was truly African.

In addition to Brazil at least two parts of Asia—West Java and southern Thailand—also cultivate the crop. Although produced only on a micro scale, this African legume serves Indonesian and Thai consumers as a soup vegetable, a snack, and a dessert ingredient. How and when it reached Southeast Asia has so far not been explained.

In Malaysia, where the plant is known as *kacang poi*, it is mostly consumed as boiled nut (similar to peanut). Perlis, Kedah, and Kelantan, states bordering Thailand, are apparently the only ones to grow it so far. The crop is produced like peanut, but is said to yield less. It is commonly marketed as raw nuts at farmers and night markets. In addition, small amounts are imported from Thailand.

seeded pods, but ecotypes collected in Congo frequently had pods with three seeds.[23] Mature pods are indehiscent, often wrinkled, ranging from a yellowish to a reddish dark brown color. The seeds are round, 1-1.5 cm in diameter, and come in colors varying from white to creamy yellow, brown, purple, red, and black. Most are a single color, but some are mottled, blotched or striped.

Distribution

Within Africa Although wild types are still to be found in tropical eastern Africa, the crop is believed to have originated in the region encompassing northeastern Nigeria and northern Cameroon. It is today

[23] Goli, A.E. and N.Q. Ng. 1988. Bambara groundnut multi-location yield trial. Pp. 11-12 in *Annual Report, Genetic Resources Unit*, IITA.

cultivated throughout tropical Africa's drier areas, including Madagascar. In southern Africa, Zimbabwe is the center of production.

Beyond Africa Botanists in earlier times identified specimens in a number of tropical locations, including India, Philippines, Fiji; Sri Lanka, New Caledonia, and Surinam. Whether the plants still exist there is unknown; probably they were in botanic gardens and research institutions, rather than farmers' fields.

The present degree of cultivation outside Africa is basically negligible. However, the crop still grows in Brazil as it has since the 1600s. It is also cultivated in West Java and southern Thailand. Although produced only on a small scale, this African legume serves Indonesian and Thai consumers mainly as a soup vegetable, a snack, and a dessert ingredient.

Horticultural Varieties

Strictly speaking, there are no formal varieties. Every planting now uses mixtures of landraces mainly identified by the size and color of the seed and the shape of the leaf.

Environmental Requirements

The plant grows best in climates used for growing peanuts, maize, millet, or sorghum. It needs abundant sunshine, high temperatures, at least four frost-free months, and frequent rains during the period between sowing and flowering.

Daylength Most cultivars are adapted to short days of the tropical and subtropical latitudes.

Rainfall An evenly distributed rainfall in the range 600-1,000 mm encourages optimum growth, but satisfactory yields can be obtained where the dry season is pronounced. Except during the flowering period, heavy rainfall causes no problems.

Altitude Satisfactory yields can be obtained at elevations up to at least 1,600 m.

Low Temperature For optimal growth the temperature requirement is reported as 20-28°C.

High Temperature The plant seems little fazed by high temperatures. It grows, for instance, where temperatures top 40°C; areas, in other words, unsuitable for many leguminous crops.

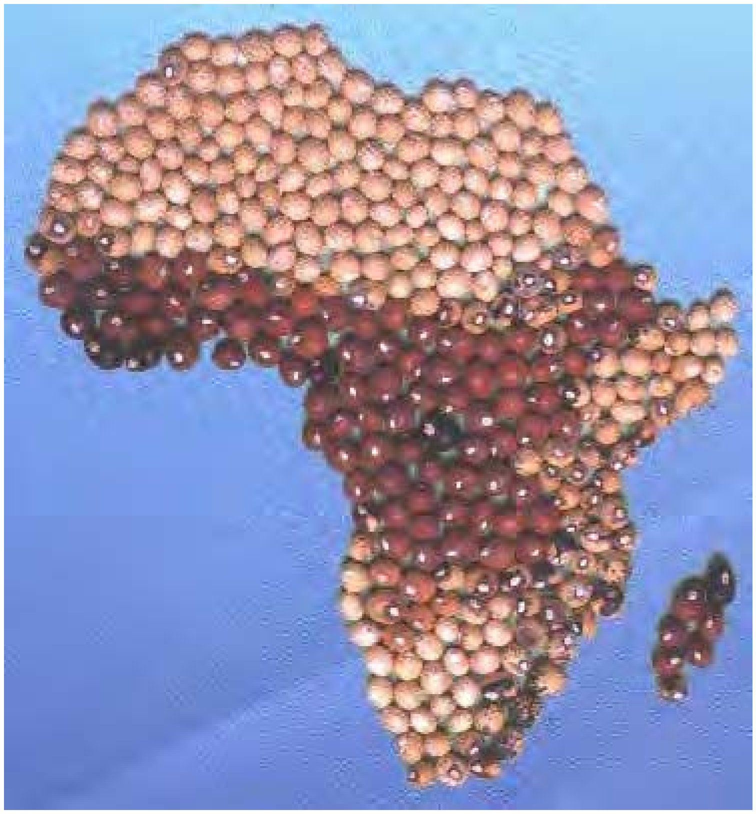
Soil The crop must be planted in loose, light soils to facilitate both the nitrogen-fixing bacteria in its root nodules and the development of the buried seeds. It also eases the task of digging up the pods. Any well-drained soil is suitable, but light sandy loam with a pH of 5-6.5 and medium to low fertility is said to produce the most seeds.

Related Species

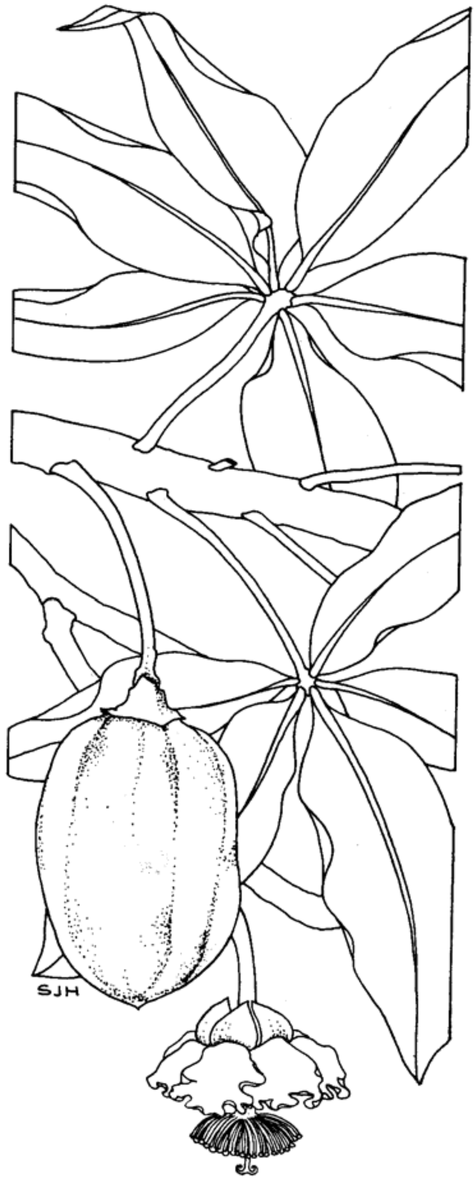
A closely similar plant, the groundbean or Kersting's groundnut,[24] also deserves attention. Its leaves are broader than those of the bambara bean and the plant is less robust. Though the pods develop underground, the seeds resemble common beans and are usually white, brown, black, or speckled in color. Their protein occurs in good quantity (19-20 percent) and is rich in the essential amino acids lysine (6.2 percent) and methionine (1.4 percent). Grown in both high-rainfall and savanna areas in tropical Africa, this groundbean survives even drier areas and is even more obscure than the bambara bean. Although the seeds are tasty, they are small and yields are poor, disadvantages likely to be correctable with appropriate research. Achieving that could unleash a high-lysine, high-methionine crop of potentially great nutritional significance.

Another virtually unknown relative is found in tropical Africa is *Vigna poissoni* (synonym *Voandzeia poissoni* Chev., also a synonym for, at least, some forms of Kersting's groundnut). Its underground beans are supposedly eaten in Benin, but we are unaware if even one agricultural or food scientist has looked into this species yet.

[24] *Kerstingiella geocarpa* Harms or *Macrotyloma geocarpum* (Harms) Maréchal & Baudet



(Werner Schenkel)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BAOBAB

A very, very long time ago, say some African legends, the first baobab sprouted beside a small lake. As it grew taller and looked about it spied other trees, noting their colorful flowers, straight and handsome trunks, and large leaves. Then one day the wind died away leaving the water smooth as a mirror, and the tree finally got to see itself. The reflected image shocked it to its root hairs. Its own flowers lacked bright color, its leaves were tiny, it was grossly fat, and its bark resembled the wrinkled hide of an old elephant. In a strongly worded invocation to the creator, the baobab complained about the bad deal it'd been given.

This impertinence had no effect: Following a hasty reconsideration, the deity felt fully satisfied. Relishing the fact that some organisms were purposefully less than perfect, the creator demanded to know whether the baobab found the hippopotamus beautiful, or the hyena's cry pleasant-and then retired in a huff behind the clouds.

But back on earth the barrel-chested whiner neither stopped peering at its reflection nor raising its voice in protest. Finally, an exasperated creator returned from the sky, seized the ingrate by the trunk, yanked it from the ground, turned it over, and replanted it upside down. And from that day since, the baobab has been unable to see its reflection or make complaint; for thousands of years it has worked strictly in silence, paying off its ancient transgression by doing good deeds for people.

All across the African continent some variation on this story is told to explain why this species is so unusual and yet so helpful. Indeed, dozens more stories surround the baobab, a species that not only incites imagination but also induces something akin to reverence. Senegal chose it for its national tree and throughout the lands below the Sahara the sight of a baobab inspires poetry, legend, compassion, even devotion. Africans everywhere almost instinctively protect each and every one.

Seen from a distance, the results of the creator's prank come into clearer perspective: baobabs certainly do seem to grow with their roots kicking the breeze. From the top of the trunk the boughs splay upward at a sharp angle, and they are crooked enough to seem like they should be underground. This eye-catching profile makes each baobab unique, and no matter how many you've seen before the shape seems always fresh.

Yet beyond the charms this tree conjures in people's minds lies a beguiling reality. Of all nature's living entities this is one of the most fascinating. For one thing, it may be exceptionally long lived, with some individuals claimed to be over 1,000 years old.[1] It is also among the biggest and bulkiest of all living organisms, having a trunk sometimes half as broad as it is high.[2] This squat stalk, its smooth surface pocked and slit as if stigmatized, is often hollow. Some monstrous specimens actually enclose a trunk space bigger than that found inside a small house. In dry areas they are commonly co-opted as village cisterns. A single bulbous stem has been known to store as much as 10,000 liters of fresh clean water. No wonder another name for baobab is bottle tree.

It is also one of the most useful living entities. On a practical level, the Africans' veneration arises because the baobab is vital to life. The bark fuels cooking stoves, pottery kilns, and baking ovens. The flexible fiber found in the layer immediately beneath the bark provides cord and coarse fabrics. The fruits are eaten with food or stirred into drinks, and provide exceptional quantities of vitamin C and other nutrients. The seeds are roasted and made into a sort of creamy butter.

The living trees are useful in their own right—not only providing shade but often providing the only splendor in an otherwise sere landscape. They also constitute handy landmarks for travelers,[3] gathering points for villagers, and silent witnesses to long abandoned villages. Nothing grows around the base, a feature emphasizing the profile, not to mention the self-sufficiency, solitude, and apparent strength of this surprising species.

In a separate volume we detail baobab fruit as well as most other products from the tree. Here we focus on the leaves and their uses.

Baobab leaf is a staple of many populations in the savanna lands just beneath the Sahara. In most places between the westernmost tip of Senegal and Lake Chad half a continent to the east this leaf vegetable is among the most common of foods. Bursting into foliage a little before the rains begin, the trees remain green until a little after the rains have ceased. In a food class renowned for transitory availability, baobab is thus a leafy vegetable that yields through a very long season.

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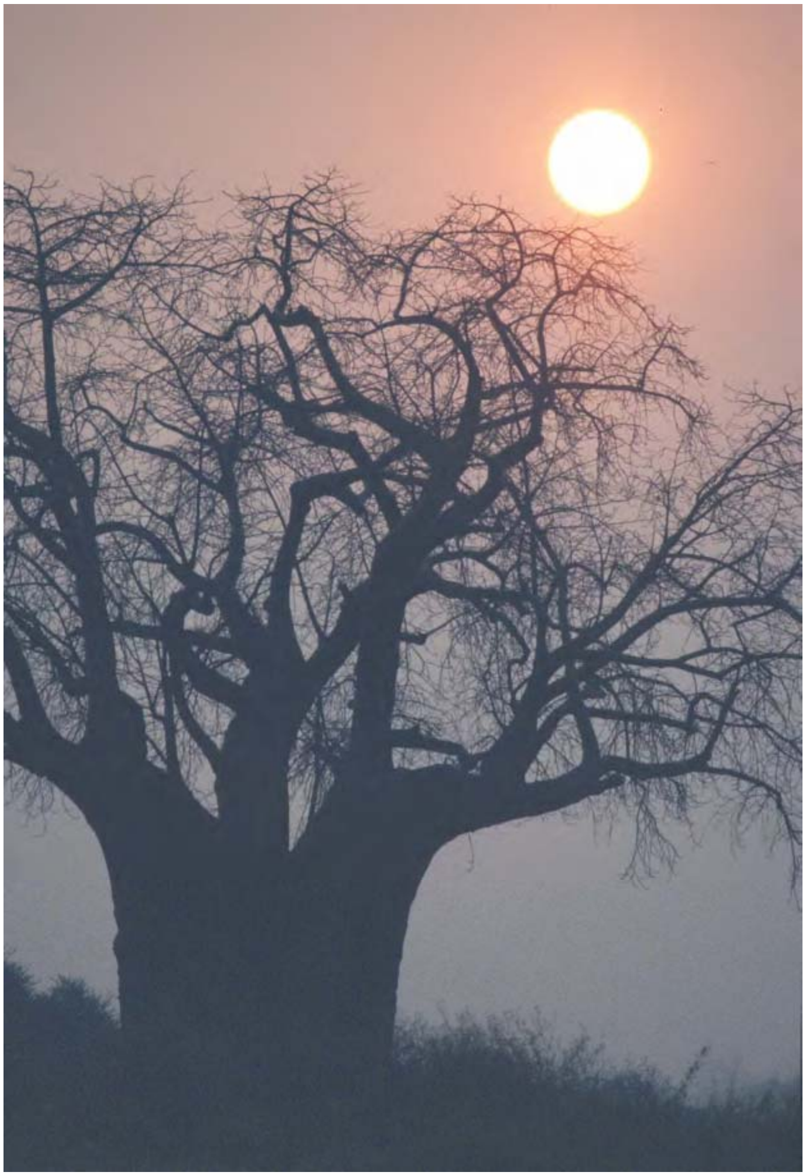
[1] Although the trunk forms growth rings, they are laid down irregularly, so a baobab's age is difficult to determine by this means. Carbon dating has put the ages of some specimens at 2,000 years, and there are claims that others have seen six millennia pass.

[2] Specimens 18 m tall with trunks 9 m across have been measured. They often form classic looking half-arches reminiscent of the flying buttresses on European cathedrals.

[3] They provide landmarks even for mapmakers—indicating locations on map sheets in otherwise featureless landscape. Large baobabs are, for instance, indicated on 1:200,000 map sheets in Mali.



Nature's most recognized silhouette? Baobabs are so distinctive there is little chance of ever mistaking one. These majestic trees are found throughout much of Africa. It is hard to conceive anything more promising for Africa's long-term future than a native tree beloved by the people, that seemingly lives forever without much maintenance, and that provides nutritional food (William F. McComas, photographed in Tanzania's Tarangire National Park)

Strangely, it is only in West Africa that baobab leaves contribute to diets in a major way. Eastern and Southern Africa have the tree but seldom consume the leaves. In the continent's western half, however, thousands of tons are consumed annually, and baobab greens are a commonplace in the markets as well as the daily meals of millions.

Baobab leaf is sometimes steamed and eaten as a side-dish like spinach, but most goes straight into soups, stews, sauces, relishes, and condiments that end up being poured over the yam, cassava, maize, millet, sorghum, and so forth to complete the main dish.[4] A recent survey in Mali found that baobab leaves occurred in 41 percent of these "soups."[5] This widely used name does something of an injustice to such concoctions, which are more akin to sauces. The leaves not only add flavor and nutritive value they thicken the mixture and give the dishes their slightly slippery texture as well as their popularity. Although baobab leaf is the most common base for these sauces, many other things, including eggplant, okra, jute,[6] tomato, onion, green peppers, and (when available) fish or meat, are also tossed in. Throughout that vast region this vegetable blend ladled like gravy over starchy staples is the most common cooked food of all.

In collecting their leaves for the evening meal, people are constantly plucking and pruning the trees, with the result that baobabs never get a chance to look natural and complete. Indeed, across West Africa they become so thoroughly picked over they look ragged, ratty, or even in the final phase of succumbing to some wasting disease.

Following the flush of new leaves early in the rainy season any surplus harvest is put aside to dry. In desiccated form, the leaves keep well—surprisingly without losing their glutinous polysaccharides—and many months later they can be brought out and used to thicken soups just like new.

In cities, where baobabs aren't available for the picking, the leaves for the evening meal must be purchased. For many people finding the baobab money becomes a never-ending struggle: Making baobab-leaf sauce can cost the equivalent up to even a dollar a day, a fearsome price in that area, where making more than that for a day's work is rare. On the other hand, countrywomen derive small but important income from selling the leaves.

In nutritional power baobab leaf is quite surprising. According to various reports it contains 11 to 17 percent crude protein and with an amino-acid composition comparing favorably with that considered the ultimate for human nutrition. Isoleucine, leucine, lysine, phenylalanine, tyrosine, threonine, tryptophan, and valine all occur in adequate amounts. The lysine

[4] Baobab is, for instance, a major food of the Hausa-speaking peoples. A traditional Hausa lunch includes danwake, which is typically a blend of sorghum, sweet potato, cassava, potash, peanut oil, dried chile, cowpea, and baobab leaves.

[5] The next most popular, at 26 percent, was okra—a crop dealt with in Chapter 16.

[6] Although the jute used to make sacking can be eaten, the species cultivated as a vegetable is its relative *Corchorus olitorius*.

level is especially notable, since people usually eat baobab leaf along with cereals or roots, which are both comparatively deficient in this critical dietary ingredient. Wherever meat, milk, or eggs are hard to come by or excessively costly—which means most places—the leaves contribute a protein of vital quality.

Beyond quality protein, young and tender baobab leaves contain good levels of provitamin A, and it is notable that the trees thrive in the kind of dry and impoverished locales where a lack of vitamin A constitutes one of the worst nutritional deficiencies. In addition, the levels of both riboflavin and vitamin C have proved adequate in the leaf samples tested so far.

The leaf is moreover a good source of minerals, including in its tissues calcium, iron, potassium, magnesium, manganese, molybdenum, phosphorus, and zinc. A detailed analysis so convinced the authors that they wrote: "in terms of both quality and quantity, baobab leaf can serve as a significant protein and mineral source for those populations for whom it is a staple food."[7]

All in all, then, this is a tree with a capability to hold its own against cabbage, spinach, carrots, and the other vegetables that now capture the focus in textbooks, scientific reports, and foreigners' image of first-class greens. Seen in overall perspective, baobab is a native resource that provides the continent a tree cover while providing the people food. And, given some support and attention, it could contribute a lot more to the environments, nutrition, economies, and personal income (particularly women's income) of many—if not most—African nations.

Of particular importance is the leaves' potential to help women and children who are currently beyond the reach of vitamin-support programs. In Sub-Saharan Africa, some 3 million children suffer blindness caused by insufficient vitamin A. Two-thirds of those die from increased vulnerability to infection. Their mothers are hardly better off: The World Health Organization reports that women suffering vitamin A deficiency face a significantly greater risk of death during pregnancy. Vitamin A deficiency is also common in AIDS patients, and is associated with an increased mortality rate. Baobab leaf just might be a key vehicle for delivering such people from the evil of malnutrition.

PROSPECTS

At this moment, rural peoples' dependence on baobab products seems to be rising. Probably, though, this is not due to greater appreciation for the tree but due to soaring populations, falling economies, and shrinking forests. The potential for boosting this species into a vastly greater vegetable crop would

[7] Yazzie D, D.J. VanderJagt, A. Pastuszyn, A. Okolo, and R.H.Glew. 1994. The amino acid and mineral content of baobab (*Adansonia digitata* L.) leaves. *Journal of Food Composition and Analysis* 7(3):189-193.

Well-picked-over baobab forest in Senegal. The leaf of the much beloved baobab is a staple of the savanna lands below the Sahara. In an area stretching across half the continent, this vegetable ranks among the commonest foods. Bursting into foliage a little before the rains begin, the stately trees remain green and edible until a little after the rains have ceased—often half the year. In addition, any surplus harvest can be dried, in which form, the leaves keep well even under the climatic challenges of rural Africa. (Sherman Lewis)

thus seem to be exceptional.

The main first use is likely to be small-scale commerce and subsistence use. Traditionally, baobab has not been deliberately cultivated for major commercial production, however farmers in Burkina Faso and Senegal have begun organizing its production for the local markets. Reportedly, these ventures have proven profitable.

Furthermore, extending the use of baobab leaf to regions beyond West Africa offers possibilities for enhancing both the crop and its benefits to nutrition, prosperity, and the environment. In addition, as we have said, there are excellent prospects for using baobab in health campaigns, playing off the wisdom of traditional diets.

All in all, this is a species that can get to the heart of the humanitarian needs of the most malnourished continent, not to mention the heart of rural poverty and environmental destruction.

Within Africa

As a species that speaks to the African spirit—one that, in a sense, stands for Africa—the baobab has promise almost everywhere, but the commercial and humanitarian prospects are somewhat more limited.

Humid areas Uncertain prospects. Most observers would today dismiss the baobab for cultivation as a humid lowland resource. However, in certain areas the trees thrive where annual rainfall reaches 1,250 mm, actually growing with almost twice-normal speed. Indeed, along the Kenyan coast baobab grows vigorously where annual rainfall ranges up to 2,000 mm. Thus, on the issue of its tolerance of lowland tropical conditions a grave misconception might possibly be inhibiting expectations and initiatives.

Although heat and humidity may slash fruit production, they don't affect the leaves. They may in fact force even greater production of foliage. Of course, this tree grows in the open and cannot take the shady conditions of a forest.

Dry areas Excellent prospects. Baobab is common throughout West Africa's savannas, where the Sahara Desert to the immediate north is the dominant climatic influence. In this often-parched precinct baobab is not only the biggest but also arguably the best tree around. It has even been dubbed "Mother of the Sahel." People like the leaves and the production in this zone could readily be boosted for the benefit of children's eyesight, the environment, the savanna scenery, AIDS patients, and all who eat there.

Upland areas Unknown prospects. The baobab normally occupies sites below 600 m elevation, which has been considered the species' upper limit. Nonetheless, there are indications that—within reasonable limits of temperature and rainfall—niches to accommodate these trees could be found at elevations far above that supposed ceiling.

Beyond Africa

Although the baobab grows satisfactorily outside Africa, it seems unlikely to become a significant vegetable resource in locations where it is not now employed in that manner.

USES

In overall utility, perhaps no tree on earth surpasses baobab.

Vegetable As mentioned, the young leaves are used as a soup ingredient. Large quantities are consumed. The amount used in preparing soup, for example, varies depending on the taste of the cook and her level of prosperity, but one survey of 831 preparations in three Zaria (Nigeria) villages found that baobab leaf constituted between 2 and 3 percent of the whole soup.

Typically, leaves are ground up and sprinkled into the pot in which sauces are being prepared. Taken all round, this is the main form in which leaf is employed. Hausa-speaking peoples in particular consider it the main ingredient of a soup called miyar kuka (kuka being their name for dry baobab leaves). But all across West Africa these popular baobab-leaf soups are most often labeled with the Wolof name, lalo.

In Ghana baobab-leaf soup is used as weaning food. Research has shown it to be of such nutritional quality that it may be therapeutically useful in the management of protein-calorie malnutrition—the biggest baby-killer of all, and a common feature across Africa.

Forage Baobab leaves are among the livestock owner's favorite forages. They become vitally important at the beginning of the rainy season, a time of year when the old pasture has been eaten out and the new has yet to regrow. The tree's roots, when tapping into underground moisture, help generate an early flush of foliage that can make the difference in bridging this feed gap. The leaves are also eaten by large caterpillars that are themselves a valued food.

Medicinal Uses Baobab leaf powder is credited with various medicinal powers and is commonly taken as a general tonic as well as a treatment for anemia and dysentery. The leaves are also used in treating other afflictions: asthma, kidney and bladder disease, insect bites, fevers, malaria, sores, and even copious perspiration.

Beyond the leaves, there are of course other uses for the baobab. These are highlighted in the companion volume, but can be summarized as:

Fruits Reaching almost the size of melons, baobab fruits enclose packets of chalk-like pulp with an agreeable acidic taste. That floury solid is peculiarly refreshing, a feature especially appreciated in the hot zones where the tree mostly occurs. Although much goes into tasty and nutritious drinks, most is eaten with milk or with milk and porridge. The fruits are also sucked as a snack or ground into flour and added to cereal dishes. The seeds are not only roasted and made into a sort of creamy butter, they are used to strengthen soups.

Seeds Embedded in the fruit pulp are seeds whose kernels not only are tasty but high in protein. They too are widely eaten. They are sometimes prepared by roasting. Indeed, during the "hungry season," roasted baobab seeds become many people's staple. Their flavor has been likened to that of almonds.

Flowers As a source of nectar baobab flowers are excellent. All in all, these trees contribute greatly to Africa's honey supply.

Trunks The bark often forms cavities deep enough for animals, and even people, to find homes. The gigantic trunk is occasionally coopted for use as storage sheds, bus stops, bars, dairies, toilets, watchtowers, grain stores, shelters, stables, or even tombs. Water stored inside may keep for months or even years without fouling (as long as the hole in the trunk is carefully covered to block contamination from the outside).

Roots The tender root of the very young baobab is edible. Older roots are not, but they provide a strong red dye.

Amenity Plantings Baobabs are planted for shade, shelter, boundary-markers, and general beautification. They typically cluster around villages, but each one—even standing alone and unattended in the vast savanna—is individually owned or at least commandeered by "squatters" who first prune off the branches—partly to increase productivity, but mainly to secure their claim to the tree for the season. Large groupings are either part of living villages or silent witnesses to dead ones. Sometimes it is hard to tell whether people naturally settle close to these useful trees or vice versa.

Fiber The stringy inner bark yields a particularly strong and durable fiber that provides such things as rope, thread, strings for musical instruments, and a paperstock tough enough for bank notes. Some is woven into fabrics that are valued for making (among other things) the bags used for hauling and storing everyday goods. These fabrics can be waterproof, and Senegalese artisans weave them into rainhats and even drinking vessels.

Fuel The thick bark, the fibrous husks of the fruit, and the dense shells of the seeds make useful fuels. Although the bark is burnable, the spongy material making up the bulk of the trunk (i.e. the part inside the bark) is usually too sodden to even smolder until thoroughly dry.

NUTRITION

Baobab leaf provides at least four nutritious ingredients: protein, vitamins, minerals, and dietary fiber.

Protein As noted, fresh leaf samples are protein rich. Leaves analyzed in the above-mentioned report contained 10.6 percent protein.[8] The amino-acid composition—the one comparing favorably to the "ideal"—was valine (5.9 percent), phenylalanine/tyrosine (9.6 percent), isoleucine (6.3 percent), lysine (5.7 percent), arginine (8.5 percent), threonine (3.9 percent), cysteine/methionine (4.8 percent), and tryptophan (1.5 percent). In sum, there were adequate amounts of all the essential amino acids excepting the two, cysteine and methionine, containing sulfur.

Vitamins Baobab leaves contain a very high level of the carotenoids that give rise to vitamin A. The actual amounts (9-27 mg per kg) depend on the tree and on the method of drying. The carotenoids are not unlike those found in carrots (and mangoes), but are less concentrated and less available than their carrot counterparts.[9]

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[8] Other researchers have reported up to 15 percent protein. Measurements are on a dry-weight basis.

[9] About 1600 ug./100 g retinol equivalent. Becker, B. 1983. The contribution of wild

Recent research determined the levels of provitamin A for various leaf types, drying methods, and processing systems.[10] It was found that drying the leaves in shade rather than sun doubled the leaf powder's provitamin A content—a very important discovery for those using baobab in health campaigns. The age of the tree had no effect on provitamin A levels but leaves from small-leafed trees contained more than from large-leafed trees.

Minerals The leaf samples are also high in ash (9-13 percent), which includes minerals such as calcium, magnesium, manganese, potassium, phosphorus, iron, sodium, and zinc. In certain samples, however, some of these elements occurred at lesser levels, probably reflecting deficiencies in the soil where the particular tree grew. One test indicated that 100 g of baobab leaves provide about three times the daily calcium requirements, twice the daily magnesium and copper requirements, and four times the daily manganese requirement. It is unclear how available these minerals are in fresh or processed leaves.

Fiber The leaf is also high in crude fiber, with levels of 15 to 18 percent measured. They also have an important amount of mucilage.[11]

HORTICULTURE

Little is known about how best to cultivate and care for baobab. Whereas the tree is common and well distributed throughout the Sahelian and Sudanian zones, few of the specimens there were deliberately planted—most arising as part of the natural system and subsequently preserved when farmers cleared the land. Concentrations of deliberately planted trees occur mainly in and around village sites.

We have earlier noted that Africans everywhere almost instinctively protect each and every baobab. Part of the reason, of course, is that the trees supply food and traditional medicines for both humans and their livestock. This resulting parkland system, in which the fields are everywhere dotted with trees, is the most widespread form of agricultural production over much of West Africa. Moreover, the practice of fallowing the land after cropping it for several years inadvertently helps native trees such as baobab to regenerate.[12]

Although this protection and natural regeneration are currently the main means of fostering baobab, the species can be propagated from seed. Simple

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planta to human nutriton in the Ferlo, Northern Senegal. *Agroforestry Systems* 1:257-267.

[10] Information from J. Scheuring.

[11] Gaiwe, R., T. Nkulinkiye-Neura, E. Bassene, D. Olschwang, D. Ba, and J.L. Pousset. 1989. Calcium et mucilage dans les feuilles de *Adansonia digitata* (Boabab). *Int. J. Crude Drug Res.* 27:101-104.

[12] Farmers fallow land mainly to relieve weed pressure and restore soil fertility. However, they do protect baobab trees that emerge as a result.

treatments are needed to overcome a reluctance to germinate in a timely manner. After a 5-minute soak in boiling water the seeds germinate uniformly and usually within three weeks.

Transplanting bare-root seedlings is satisfactory. For example, on the Seno Plain, along Mali's border with Burkina Faso, villagers often raise baobabs within their own courtyards and nurture the seedlings until they are 2-3 m tall, then transplant them to the edges of their fields.

Despite a reputation for slow growth, baobab seedlings on favorable sites have been known to reach 2 m in height in 2 years and become 12 m tall in 15 years. Although far above the norm, this shows the potential in the plant given horticultural attention.

Seedlings and young trees need careful protection. In fact, in the open savanna comparatively few small baobabs are ever seen, mainly because they fall victims to cattle, goats, ground fires, or overzealous individuals picking them to death for soup leaves.

Mature trees, however, have few enemies. No serious pest or major disease is known. Neither cattle nor goats do serious harm. Not even overzealous pickers can seemingly set back a healthy old baobab. Being a trunk-succulent, the tree resists both fire and drought. However, lightning, severe winds, and (in southern and eastern Africa) elephants can break the branches and bring down even the biggest of these botanical monarchs.

HARVESTING AND HANDLING

There is no secret about harvesting baobab leaves. People (mostly small boys) literally clamber over the trees, plucking off every young leaf within reach. Ladders of steps are often slashed into the side of trees to allow easy access to their upper stories. Many trees are kept basically denuded throughout their life. Some are pollarded, their top branches cut back to the trunk to induce a dense growth of new shoots. In both cases, flowering is suppressed and, perhaps because of that, the leaves sprout in abundance.

Because the leaves are available only during the rainy season, women dry any surplus and store it for use up to a year later, for times when vegetables are not only difficult to find but expensive. This propensity for easy storage also allows the leaves to be sold at the time when the traders pay the best prices. In good years this provides a small, but important, source of income.

In better-watered zones or in village gardens where each tree can be pampered through the dry season, baobabs prosper and often remain in foliage year-round.

LIMITATIONS

Although the leaves are rich in various nutrients, the quantities touted in research reports might not (at least in theory) reflect those actually reaching

the body. At present, no one knows about the digestibility of the different ingredients, but it is possible that phytic acid, oxalic acid, hydrocyanic acid, and tannins occur in high enough levels to interfere with the body's use of proteins and calcium.

Researchers in Mali discovered that the baobab powders on sale in public markets differed widely in nutrient content. They urged consumers give preference to those with darker green color and a good all-round baobab-leaf smell. "Based on its provitamin A content," they wrote, "baobab-leaf can be very effective at saving eyesight, but only as long as care is taken to handle the leaves in ways that preserve the vitamin. To maintain a high level of provitamin A level in dried leaves, it is important NOT TO DRY THE LEAVES IN THE SUN. Leaves dried in the sun have only half the provitamin A levels of leaves dried in the shade. [Also] it is recommended to store dried whole leaves rather than dried leaf powder in order to maintain good provitamin A levels. Provitamin A tolerates cooking, but is degraded by overcooking."

NEXT STEPS

A tree as productive and as important to people as this one is worthy of massive and pan-African research. Programs dealing with food, nutrition, forestry, agriculture, agroforestry, rural development, home economics, horticulture, and other subjects should embrace this species as a potential tool for helping achieve their individual goals. Combining the traditional, Africa-wide knowledge with modern scientific understandings could boost baobab to a far greater furnisher of food from Senegal to Mozambique and Madagascar.

This tree is already so well known that basic research is not essential to progress. Existing knowledge and the germplasm on hand can be used to mount planting and protection programs throughout its range. These can be big or little, concentrated or dispersed, rural or suburban.

Protection As noted in the volume on Africa's cultivated fruits, baobab is a candidate for self-motivated forestry. Indeed, if a few people take the initiative, it is not inconceivable they will spark an Africawide "Baobab Movement." Mass-producing saplings for the rural poor seems a good start. Such an endeavor would eventually do more than just feed the growers; it could create a critical mass of trees for producing leaves (as well as fruits and bark fiber) on an industrial scale. The tree would then move from a beloved but scattered village companion into a major continental resource. Although one must wait years for the fruits to form, leaves sprout from the start and the leaf harvest can begin after only brief delay.

One way to foster immediate increases is to raise the juvenile survival rate. With their slim stems and simple leaf form, saplings look too handsome to be baobabs. Thus, although old baobabs are venerated as personal

property, young ones go unclaimed, and quickly fall to ground fires, goats, and galoots stripping the leaves for dinner. This ignorance and mindless plunder are major constraints to further development and need to be reduced by programs that enlighten the populace to the potential inherent even in the skinny little young trees.

To outsiders, West Africa's tree-dotted savannas may look almost like recreational areas, but they are in fact nutritional ones. Products from various woody species in this parkland agroecosystem feed the rural population throughout the year and also contribute snacks during the period when other foods are scarce. This trees-and-farmland combination is an agricultural system that needs to be preserved; focusing on baobab is one way to help bring that about.

Education Whereas millions of people use baobab, few are aware of its notable health benefits. Although vitamin A deficiency is a chronic health problem in places such as rural Mali, the curative nature of baobab leaves goes almost unappreciated by the masses. In the fight against malnutrition these leafy materials offer sweeping future advances. They are on hand, they are known, and they can be marshaled to help children and others. This can be brought about through education, not excluding advertising.

One reason why more baobabs aren't planted is that people believe the tree grows so slowly that they'll never see the results. In addition, many people refuse to plant any species that regenerates spontaneously—why waste effort when nature will do the job for you. Again, education could be employed to motivate millions to plant more baobabs.[13]

In some areas cultural taboos may slow this species' greater use. In parts of the Gambia, for instance, baobabs are considered too evil to plant nearby. And in Mali during October and November prices for the leaves drop because it is said that during that "cool" season they cause the lips to crack. There is a need for broad education on what we really know about baobab—and what we don't.

Expanding the Use Although among the most widespread and most appreciated native plants, only West Africans use baobab much as a vegetable. Elsewhere, the trees abound but the leaves go uneaten. This opens new possibilities, of course, but before the production of leaves is promoted outside West Africa it would be wise to determine why they are rejected there now. According to one report, the trees used for vegetable purposes derive from a glabrous variety, with hairless leaves. The author implied that the tomentose variety, whose leaves are covered in down, furnish good fruit but bad (in the culinary sense) leaves. This perhaps explains the strange

[13] Actually, this attitude has already begun changing. "On my last two trips through Mali and Burkina Faso," one of our reviewers wrote, "I was very impressed by the number of baobab I saw growing in peoples kitchen gardens."

dichotomy of only one region eating the leaf. Should this observation prove true, then the hairless (good-vegetable) types and the hairy (good-fruit) types should be tested throughout the continent. This would involve a swap of germplasm likely to benefit all.

Nutritional Research With their 15-percent crude protein content, the leaves should be a useful source of this vital food type, but the crude fiber and tannins may reduce its digestibility. This needs investigation.

Similarly, the leaves are rich in calcium, but how much is absorbed by the body is uncertain because the leaves also contain gums that may impede its absorption. Phytic acid and oxalic acid, which are known to adversely affect their mineral utilization but whose levels are probably only marginally problematic, may also affect the availability of calcium, not to mention magnesium and iron.

Studies of the fate of vitamin C under various food-processing regimes would provide helpful guidance for best processing practices.

Baobab-leaf could become an important export, but any formal trade will require better governmental policies as well as better processing. The first step is to learn the potentials of the various products as well as the constraints associated with their manufacture and marketing.

Horticultural Development In baobabs grown for edible leaves the selection of elite types is less important than in those grown for fruits. Nonetheless, it seems well worth searching for highly productive forms that can foster and facilitate the species' progress toward becoming a better vegetable resource. Selection for leaf quality is the necessary research ingredient. Issues might include flavor, digestibility, carotenoid content, and ability to make soups with just the right slipperiness on the tongue. As noted, trees with small leaves have been recommended.

Vegetative propagation would be useful for making such advances, and the best techniques need to be worked out. This alone will foster new plantings, not to mention new profits and perceptions.

The plant's ecological tolerances and preferences are poorly understood. Although it appears far from picky about where it grows, at least one researcher has noticed "a tremendous response to choice of planting site, even to microsite."

On the surface, this would seem a good species for developing miniature gardens, as has been done with apples in England. By keeping the trees topped and pruned to human height, the leaves would be always within easy reach. Should this prove feasible, baobabs could be grown and plucked like tea plants. Women and girls could then participate equally in the harvest.[14]

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[14] This may be somewhat fanciful: One reviewer wrote: "I'm a bit skeptical of this as the tree's crowns are not very full. A stunted tree would most likely have very few leaves." The key would be pruning at a very young age and, perhaps, the identification of plants

SPECIES INFORMATION

Botanical Name *Adansonia digitata* Linnaeus[15]

Family Bombacaceae

Common Names

Afrikaans: kremertartboom
Arabic: hahar, tebeldis; fruit: gangoleis
Bambara: sira, n'sira, sito
Burkina Faso: twege (Moré)
English: baobab, monkey bread, Ethiopian sour gourd, cream-of-tartar tree
French: baobab (tree); pain de singe (fruit), calabassier, arbre aux calebasses
Fulani: bokki, bokchi, boko
Ghana: odadie (Twi, in the south), tua (Nankani, in the north)
Jola: buback
Kenya: mbuyu (Swahili); mwamba (Kamba); olmisera (Maasai); muru (Bajun);
Malawi: manyika: mubuyu
Malagasy: Bozo (Sakalava dialect)
Mandinko: sito
Manyika: mubuyu
Ndebele: umkomo
Hausa: kuka (dried leaves), miya kuka (soup)
Yoruba: luru
Portugese: imbondeiro
Shona: mayuy, muuyu, tsongoro (seeds)
Sudan: tebeldi, humeira
Swahili: mbuyu
Tsonga: shimuwu
Tswana: mowana
Venda: muvuhuyu
Wolof: bui, lalo (leaf powder)
Zulu: isimuhu, umshimulu

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with many leaf buds low on the trunk.

[15] The genus was named for the French naturalist, Michael Adanson (1727-1806), who was among the first to study the botany of Senegal. He coined the word "baobab" and also devised a system of classifying and naming plants based on all their physical characteristics and emphasizing families. To this, the Swedish botanist Carolus Linnaeus was much opposed, and eventually his own system superseded Adanson's. Nonetheless, Linnaeus honored his rival by naming the tree's genus *Adansonia*. Linnaeus sometimes selected names meant as insults, so the fact that baobab is fat and ugly might also have been in his mind.

Description

Baobab typically grows up to 20 m tall and its sharply tapered, but very swollen, trunk sometimes reaches a circumference of 30 m. This immense girth and stiff branching give the impression of a bottle full of twigs. A spongy mass of parenchymous tissues fills the thick trunk, which typically becomes saturated with water and is often hollow. The smooth, metallic-gray bark has a remarkable ability to heal any wounds. Roots extend far from the base of the tree and probably account for the dearth of nearby vegetation. There may be a taproot as well, though reportedly not deep.

The leaves are compound and digitate, usually with 6-8 oblanceolate leaflets. The common stalk is usually about 8-15 cm long and the individual leaflets lack stalks. Whether in full leaf, in flower, or in fruit, it is one of the most beautiful and fascinating of trees. Whole plantings can become bespangled with white blossoms that attract bats, giving rise to masses of fruits hanging on long stems like ornaments.

Distribution

Within Africa This species is found throughout tropical Africa, but especially in the sub-humid regions and the semi-arid zone to the south of Sahara. Its northern limit (in Senegal) is about 16°N; its southern limit is about 15°S in Angola to 22°S in Botswana and to 24°C in Mozambique (at Chokwe). The species is also a famous feature of the Madagascar landscape, but *Adansonia digitata* seems not to be native there, the homeland of the genus. It perhaps arrived with Arab traders who carried the seed out of Africa centuries ago.

Beyond Africa Baobabs have long been planted in locations throughout the tropics, and have been introduced into the Americas and Asia. Its widespread occurrence in India, Sri Lanka, and elsewhere around the Indian Ocean is due to Arab traders who carried the seed out of Africa centuries ago. It is also well known in the far north of Australia, and is scattered as an ornamental through much of the tropics.

Horticultural Varieties

No formal varieties have been recorded for vegetable use. However, in the Sahel four baobab types are loosely recognized: black-, red-, and gray-bark, and dark-leaf. Dark-leaf baobab is preferred for use as a leafy vegetable, while the black- and red-bark baobabs for their fruits.

Cultivation Conditions

Generally, baobabs occur in semiarid to subhumid tropical zones. These light-demanding trees do not like the dense tropical forests.

Rainfall Baobabs are most common where mean annual rainfall is 200-1,200 mm. However, they are also found in locations with as little as 90 mm or as much as 2,000 mm mean annual rainfall.

Altitude The tree can be found from sea level to 1,500 m (notably in eastern Africa), but mostly occurs below 600 m.

Low Temperature Baobab is said to thrive where mean annual temperature is 20-30°C. It succumbs to frost. Reportedly, germination is achieved only when soil temperature exceeds 28°C.

High Temperature No limits within Africa. It is adapted to at least 42°C (measured in the shade).

Soil Grows on many different soils but develops best on calcareous substrates and on deep, slightly moist sites. Does not tolerate seasonally inundated depressions with heavy clay soils. Despite this intolerance to waterlogging, it thrives along the banks of rivers such as the Niger. Reportedly tolerates laterite as well as relatively alkaline (e.g. limestone) soils. For reasons not explained, it apparently performs poorly in the sandy "millet" soils of the Sahelian zone.

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CELOSIA

Of all the world's vegetable crops celosia is far and away the prettiest. Deriving from the Greek word 'kelos,' meaning burned; the name itself refers to the plant's brilliant appearance and striking flame-like flowers. In a hundred nations the showy heads of this species[1] seem to outshine the sun in gardens, window boxes, streetside displays, and floral exhibits. Not only are the flowers richly hued, their deep-green foliage may also be shot through with streaks of red or purple pigment. As a result, celosia can be eye catching even before it blossoms.

But although this plant catches eyes almost everywhere on earth, few of its admirers know that it is edible, let alone that it is an important leafy vegetable in parts of tropical Africa. In Nigeria, Benin, and Congo, to name just three countries, the fresh young leaves are a common item of diet. They are primarily eaten in a dish prepared from various vegetable greens, combined with onion, eggplant, hot peppers, palm oil (or other vegetable oil), and fish or meat. Sometimes, peanut butter is also added as a thickener. All the ingredients are added to one pot, and brought to a steady boil to produce a tasty and nutritious "soup."[2]

To such dishes celosia leaves certainly contribute their share of nutrients, including calcium, phosphorus, iron, and vitamins, as well as not a little protein. Among people in the know, these dark-green leaves are valued especially for physical (and, at least according to rumor, sexual) stamina.[3]

This intensively cultivated leafy vegetable usually grows about a meter tall but can tower well over 2 m.[4] Two types predominate: One bears

[1] There are 60 *Celosia* species but this chapter refers mainly to *Celosia argentea*, the only one widely planted as an ornamental and food crop. A commonly seen synonym (applied selectively to one monstrously distorted form) is *Celosia cristata*. Another is *Celosia trigyna*.

[2] Information from Haroun Hallack.

[3] "Sokoyokoto," the plant's name in southern Nigeria's Yoruba language, literally means "the vegetable that makes your husband's face rosy," which we think is a wry—maybe sly—joke shared among women in the marketplace.

[4] The plant is a member of the Amaranth family and shares many features with members of the genus *Amaranthus*, such as broad edible leaves with high protein content and

brightly colored flower heads that look like soft, fluffy plumes and remind the observer of crimson, scarlet, or gold feathers. The other is a grotesque genetic anomaly whose flowers are crammed together into wavy lines. These massively wrinkled yellow, orange, crimson, or pink crests often resemble cock's combs. Other variants look like some bright brain coral that inadvertently crawled up out of its habitat beneath the tropical seas.

Because of its flavor, food value, and familiarity, the crop is widely consumed in several parts of Africa. It is, however, of greatest importance in Nigeria and nearby countries. The leaves, young stems, and young flower spikes are handled like spinach. They go into soups and stews, and are served as a nutty-flavored side dish with meat or fish or more commonly with a cereal-based main course such as maize porridge. In some places the leaves are finely chopped and sprinkled into the cooking pot. The flavor is reportedly pleasant, mild, and entirely lacking the bitterness that sometimes spoils other leafy vegetables. The nutritional value is roughly like that of other leafy vegetables.

Despite its African origin (a claim that is not without dispute), celosia is known as a foodstuff in Indonesia and India. Moreover, in the future it might become more widely eaten, especially in the hot and malnourished regions of the equatorial zone. In that regard, it has already been hailed as the often-wished-for vegetable that "grows like a weed without demanding all the tender loving care that other vegetables seem to need."[5]

Because of its wide tolerance to both tropical and dry conditions and because it is usually unaffected by pests, diseases, or soil type, it is among the most promising greens for harsh or fickle growing conditions. The plants spring up with surprising vigor from each tiny seed. They have especial promise for cultivation near millions of huts and hovels, whose occupants can then both enjoy these flamboyant floral accessories and also pluck off some leaves each day and drop them into the soup pot. However, it should be noted that to yield well they need fertile soil.

For subsistence production these supremely self-reliant and uncomplicated resources seem ideally suited. The ornamental form is already spread worldwide and is often to be seen growing, uncultivated and happy as a weed. They propagate easily, require little care, and often reseed themselves year after year. Kaphikautesi, a name used for this plant in

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flowers and seeds produced in dense spikes. Nonetheless, *Celosia* is a separate genus and differs in having the normal C3 photosynthetic pathway rather than the unusual C4 cycle that endows drought tolerance on amaranths. This present chapter should be read in concert with the first chapter, which details issues written with leaf amaranths in mind but that also relate to celosia, which appears to be a good alternative leaf vegetable to local amaranths where they might tend to be susceptible to insect pests.

[5] "Every place I have tried it," writes Martin Price of Florida, "it grows with no work. We have had no disease problems and very little insect damage. It reseeds itself abundantly and new plants have come up in the immediate vicinity."

Perhaps the prettiest of all vegetable crops, celosia is used as an ornamental almost everywhere on earth. But few of its millions of admirers know that it is a common item of diet in parts of tropical Africa, where it is native. The fresh young leaves, young stems and young flower spikes are used to produce a tasty and nutritious "soup" that is a daily fare especially in West Africa. Productive and simple to grow, the plant could in the future become a much greater contributor to African welfare, especially to the hot and poorly nourished regions of the equatorial zone. (Bud Markhart)

Malawi, means "eaten by lazy ones," a recognition that not only are the plants easy to produce but that they cook quickly and with little fuss or fuel.

PROSPECTS

Celosia seems a promising green for use in the hot humid tropics, especially during the rainy season. It can be very high yielding and its young leaves have a good taste and a good nutritional value. Cheap, simple, productive, heartwarming, this crop lifts life, not only perking up the surroundings with its flowers but perking up the consumers with a healthy, nourishing food. It is an excellent vegetable type to be promoted, at least in West and Central Africa where it is already known.

Within Africa

Humid Areas Excellent. Celosia is grown throughout West Africa's warmer and wetter sections. It is, for instance, Southern Nigeria's most important leaf vegetable and is raised in myriad home gardens and farm plots, both for family and the local market. Humidity and heavy rainfall fail to limit growth, so celosia is commonly cultivated during the wet season when other crops succumb to molds, mildews, and like maladies.

Dry Areas Modest. For maximum development the plants normally require at least moderate soil moisture. Although they survive dry periods, without irrigation the level of leaf production is likely to be uneconomic in parched climes.

Upland Areas Excellent. The plant is well known in East Africa's highlands under its Swahili name, mfungu.

Beyond Africa

Throughout the world's temperate regions people enjoy this easy-to-grow short-lived (ornamental) annual during the summer months. Few, however, know that celosia is a warm-weather spinach substitute. They plant it for show rather than soup. Celosia is also eaten in India—although one report notes that it is eaten "in times of scarcity." So maybe it lacks cachet as a food there as well.

USES

Generally, celosia is used like leaf amaranth (see Chapter 1).

Leaves As already stated, the leaves—not to mention young stems and young inflorescences—are eaten as potherbs. They soften up readily and cook in just minutes. The texture is soft; the flavor very mild and spinach-like. These boiled greens are often added to stews. They are also pepped up with such things as garlic, hot pepper, fresh lime, and red palm oil and eaten as a side dish.

Forage At least occasionally the plants are chopped and used as feed for chickens. The literature also reports them being employed as forage for cattle. The foliage is, however, thought to accumulate oxalate.

Ornamental Uses African families plant celosia as a vegetable not as an ornamental, but let a few plants grow to flowering to get seed. Its use as an ornamental is hardly known in Africa, but it could be. Elsewhere in the world, this is among the most popular choices for bedding and border plants, tall backgrounds, edging, and pot and container production. The blossoms also make ideal cut flowers. In addition, they are easy to dry, being merely hung upside down in a dark, dry place for several weeks. In this form they retain their form and color and can be incorporated into dry bouquets and everlasting flower arrangements. One type, known as woolflower,[6] is especially notable, producing elegant, chaffy flower spikes that glisten even when dry as dust.

Striga Suppression The celosia plant is believed to repress striga, a parasitic weed that devastates sorghum, millet, and maize across Africa. This weed, which engenders both hunger and poverty, thrives where soils are infertile and crops ill-nourished, so it targets the poor most. Whether celosia can help farmers fight back is far from clear, but it is widely called "striga chaser" owing to a reputation for sending the weed on its way. There is not complete confirmation of such ability, but one study found that celosia stimulated striga germination and lowered overall levels 50% while increasing sorghum yields.[7]

Medicinal Uses Various medicinal benefits are widely claimed, including treatments for intestinal worms (particularly tapeworm), blood diseases, mouth sores, eye problems, chest complaints (seeds), and diarrhea (flowers). The leaves are employed as dressings for boils and sores, and the boiled vegetables are said to be slightly diuretic.

NUTRITION

Celosia's nutritional value is more-or-less comparable to that of other dark-green leaves, but it shows a large variation between samples depending on species/cultivar, soil fertility (more fertilizer means higher content of minerals, provitamin A, vitamin C), harvest stage, and moisture content.

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[6] Sometimes listed as *Celosia trigyna*, a name currently considered a synonym for *Celosia argentea*, the species of this chapter.

[7] Olupot, J.R., D.S.O. Osiru, J. Oryokot, and B. Gebrekidan. 2003. The effectiveness of *Celosia argentea* (Striga "chaser") to control *Striga* on sorghum in Uganda. *Crop Protection* 22:463-468.

Although many samples have been analyzed in Nigeria, few of the details have been published. Nonetheless, the leaves are believed to contain considerable protein and calcium as well as reasonable amounts of phosphorus and iron (which can be said for many dark-green leafy vegetables). They are also said to be good sources for vitamins A and C, although little tangible evidence for this has been presented so far. A standard analysis, several decades old, lists the following constituents (measured per 100 g edible leaf portion): water 84 g, calories 44, protein 4.7 g, fat 0.7 g, carbohydrate 8 g, fiber 1.8 g, calcium 260 mg, phosphorus 43 mg, and iron 7.8 mg.[8]

Speaking generally, the nutritional value is comparable to that of amaranth (see Chapter 1), although celosia leaves tend to contain a little more moisture.

HORTICULTURE

The plants are propagated from seed, which is normally merely broadcast on top of the soil. A temporary covering of dry grass helps protect the tiny and very vulnerable seeds from washing away under heavy rain and runoff. Once they've germinated and set down roots (after about a week in other words) the grass covering is removed.

The seeds may also be planted directly into the soil (they must be placed at a shallow depth, 0.75 cm having been suggested). Moreover, vegetable plots can be established using seedlings transplanted from a nursery when 5-10 cm tall. For best results, it has been recommended that seedbeds be well manured and kept moist. There is nothing difficult about any of this, but weeds are a concern; the young seedlings are easily smothered.

Although relatively pest-free in most regions, the roots are susceptible to nematode infection. In Nigeria the flower stalks and upper leaves are also damaged by something called "leaf-curl." Also in Nigeria the variegated locust attacks immature seed capsules and a beetle feeds on green capsules causing seed loss.

As for diseases, these usually present no problem, but a fungus producing white pustules on leaf undersides seriously damages celosia grown in Nigeria. It is recommended that the infected plants be destroyed to reduce the possibility of infecting subsequent plantings.

HARVESTING AND HANDLING

Typically, the farmer waits about a month or six weeks after sowing her plants before thinning the plot. The tallest plants (usually about 15 cm high) are removed until those remaining are about 25-30 cm apart. The excised

[8] FAO. 1968. *Food Composition Tables for Use in Africa*. FAO and U.S. Department of Health, Education, and Welfare, Bethesda, Md.

plants go into the cooking pot and represent the first of a series of harvests. As the remaining plants grow taller, the new leaves and terminal shoots are removed as they appear. This provides successive harvests every week or two until the plants get to be about 45 cm in height, a point where they turn stringy and run to seed. The harvest season typically extends for 3-5 months during the rainy season, and longer if irrigation is available.

Large leaves from young plants are best for eating, but young stems and young flower stalks may also be harvested as potherbs.

In Nigeria the quantity of leaf harvested from a 5m^2 experimental plot has been measured. The green form of celosia yielded 8 kg of leaf (the equivalent of 16 tons per hectare). The red form produced 14 kg (28 tons per hectare).[9]

LIMITATIONS

Although tough and resilient, celosia can, as mentioned, be victimized by nematodes. In this regard, a mulch that insulates and keeps the soil cool should be helpful. The plant also succumbs to water-logging or freezing temperatures.

On its face, celosia could become a weed…the world's prettiest. However, even though it already flourishes in most countries, there is little sign of it becoming a curse. Perhaps that's because it is enjoyed not only by every passing goat, pig, or cow but by people as well.

When the leaves are boiled, much of the pigment dissolves, turning the cooking water dark, ugly, and unappetizing. Nevertheless, when the leaves are fished out they retain their pleasant green color. The black cooking water that remains should be discarded because it likely contains dissolved nitrates and oxalates.

NEXT STEPS

This crop needs exploratory investigations and documentation. Country reports from Nigeria, Benin, Cameroon, Congo, and other celosia-eating nations would provide valuable baseline data on botany, plant physiology, and growing requirements, as would collation of worldwide experience.[10]

In addition, this productive, hardy, and attractive plant merits trials in many more areas. Such trials are likely to attract a lot of attention and spearhead the diversification of food crops in new places.

Nutrition The nutritive qualities need to be pinned down. Although details are sketchy, the leaves are rich in protein (almost 30 percent of the

[9] Tindall, H.D. 1983. *Vegetables in the Tropics*. Avi, Westport, Connecticut.

[10] These might best be circulated via the Internet, because published versions of such reports typically take years to emerge and end up accessible mainly to professionals and already out of date.

dry matter), calcium, phosphorus, iron, and provitamin A and vitamin C. Not only does this need confirmation, but the presence and effects of possible antinutritional factors or toxins should be determined.

Food Technology Now is the time to fill in basic data on celosia quality, cooking, and consumption. It could engage the gamut of food science, including storage, handling, cooking trials, and use of leaves in foods.

Horticultural Development Wherever vegetable-research programs occur, celosia should be entered into trials and research activities. Myriad questions and uncertainties remain to be fully answered, especially optimal ways to cultivate the crop for food production.

Striga Chaser Knocking back this parasitic plant would, by itself, boost the production of food in Africa. Outsiders can hardly imagine the deadening dismay of seeing striga breaking out in your fields. A farmer noticing the pink flowers spreading through the maize or millet crop can do nothing but resign to suffer. Those little blossoms mean more work, less income, more hunger. The family may pull some out, but the damage began long before those flowers appeared. Even rotating the crops or applying fertilizers does little to stop the weed's spread. Moreover, each striga plant yields thousands of seeds, which means that the farmer's crops will be stunted for years to come. As we have indicated, there is no formal confirmation of celosia's reputation as a "striga chaser" and now is the moment to rectify that.

SPECIES INFORMATION

Botanical Name *Celosia argentea* L.

Synonyms *Celosia plumosa* (plume type)

Family Amaranthaceae

Common Names

English: celosia, cock's comb, quail grass, woolflower
French: célosie, crete de coq
Nigeria: sokoyokoto, soko, aodoyokoto
Spanish: mirabel
Sudan: bambit (Kord), el bueida (Ar), danab el kelb, sheiba (Ar)
Swahili: mfungu (Swa)
Yoruba: shoko, yoko
Malawi: kaphikaulesi, chinkanya (Ch), ndangale (Ch), munsungwe (To), nyasungwi (T), chala cha nkhwale (Nsanje name for red kind), nsanzazywale (Nsanje name for green kind).

Zimbabwe: mundawarara (C), isihlabe (Nd), sunku (To)
Zambia: kapiko, lukuli, kalume, kapikolesi
Kenya, *Tanzania*: mfungu (Swa)
Benin: Avounvo
Uganda: ekaliyo (Kmj)
Ethiopia: belbila (Am/T), birsir, shilobai (T)

Description

Celosia is an erect annual herb, normally about 1 m in height but sometimes much taller. The green type—the one most commonly used for food—has few branches, at least until it approaches the time for flowering. The leaves are alternate, light green, and not unlike amaranth leaves to look at. They are typically 2 x 6cm, although those on flowering shoots are slightly longer. Even the green foliage may contain large amounts of betalain pigments.

The often brilliantly colored flowers are borne in dense heads. Most occur in spikes, and stand like spears in the garden bed. But certain cultivated forms have compact or feathery clusters due to fasciation, the accumulation of genetic malformations that are of huge interest to botanists. Gardeners, in other words, love these freaks of nature.

Celosia flowers yield large numbers of seeds that are about 1 mm in diameter and are normally black.

Distribution

Although the plant is known worldwide, its use for food is geographically much more limited.

Within Africa The plant is common in West Africa, from at least Sierra Leone to Nigeria. It is also known in Ethiopia, Somalia, Kenya, and other parts of East Africa. In Central Africa it is found in quantity in Congo as well as probably most surrounding nations. *Celosia argentea* is an important cultivated vegetable in the rainforest zone of Nigeria, Benin, and (much less) Cameroon, Gabon, Togo. The wild form (sometimes referred to as *Celosia trigyna*) is a potherb throughout the savanna area of tropical Africa.

Beyond Africa According to old reports, the leaves have been used as spinach in at least Sri Lanka, Yemen, Indonesia, and the West Indies. They don't seem to have caught on widely, though.

Horticultural Varieties

In terms of celosia as a food crop, there are few horticultural varieties as such. However, in West Africa (especially Nigeria) two distinct forms are recognized. Green soko is erect and up to 150 cm tall. Red soko, on the other

hand, is taller (generally reaching 180 cm) and more spreading and its leaves have a distinct purple marking. Although leaves from both forms are equally good to eat, the green-leafed type is more popular as a food crop.

Environmental Requirements

The exact environmental requirements are unknown, but that hardly limits the crop because it is adaptable enough to perform well under diverse climates.

Photoperiod At least the West African vegetable species (*Celosia argentea*) is a short-day plant. And it needs high light intensity to maintain regular leaf development. Flowers rarely form in seasons and locations with long days.

Rainfall Generally more than 600 mm. Heavy rainfall will not limit growth but the plant can be sensitive to drought.

Altitude Grows well in low altitudes; but occurs up to 1,700 m in Ethiopia and occasionally up to 1,500 m in the Himalayas.

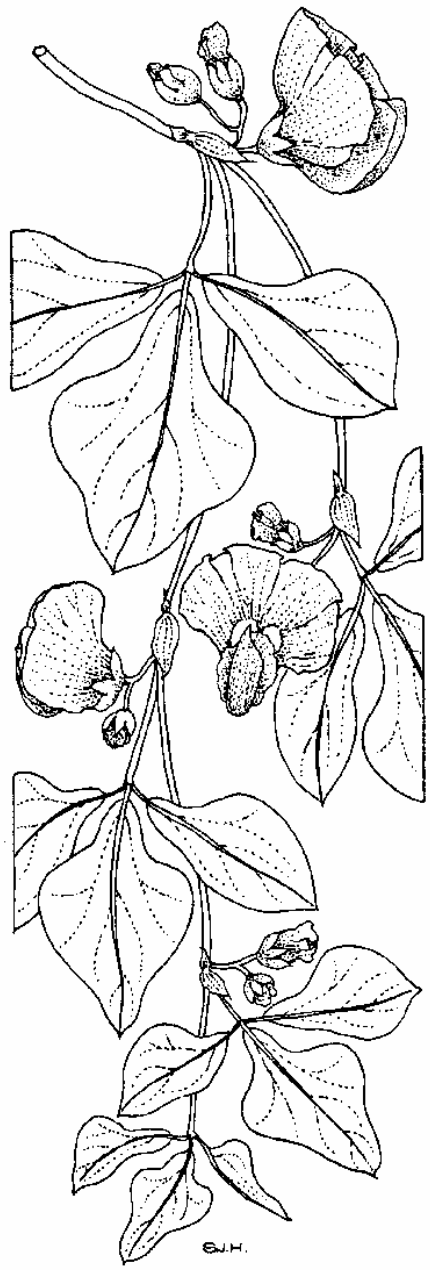
Low Temperature Must be planted when all danger of frost has passed.

High Temperature A stable high temperature of 20-25°C is suitable for both edible varieties. But celosia does quite well in Florida's cool winter as well as its hot summer.[11]

Soil Celosia tolerates many different soil conditions, although high levels of organic matter encourages good yields and reduces damage from rootknot nematodes

[11] Information from Martin Price.


REPUBLIQUE POPULAIRE DU CONGO
CELOSIA CRISTATA
2F
FLORE TROPICALE



Vigna unguiculata

5

COWPEA

Considering all the protein sources that might possibly help Africa's malnourished millions, none seems more promising or more practical than grain legumes. Legume seeds famously deliver the amino acids needed to grow or repair protein-based tissues such as brain, nerve, and muscle, as well as to construct the enzymes and proteinaceous hormones necessary for normal life functions. As tools for balancing nutrition they can have a powerful overall effect among the impoverished masses. By providing protein (not to mention vitamins, minerals, and energy), they make main foods—notably, the bulky staples, such as rice, maize, cassava—work better in the body. In this sense, they help increase the bioavailability of other nutrients. Grain legumes, in other words, act like nutritional cogwheels, making everything else go round and round in proper order.

Luckily for the particular malnourished millions in Africa there are grain legumes for almost every local soil and climatic zone.[1] In the specific areas most at risk of hunger and malnutrition, though, the leading locally domesticated candidate is cowpea. Although hardly known in global terms, cowpea constitutes Subsaharan Africa's most widely planted native legume. At present it is the second most important grain legume continent-wide; only peanut—a native of the Americas—occupies more African farmland. West Africa's farmers alone grow cowpea on an estimated 6 million hectares. More than 95 percent of the world crop comes from that area; Nigeria, the biggest producer, grows an amount variously estimated at several million tons a year.

Given quantities like that, one might question this species' inclusion in a "lost crops" book. But the cowpea's widespread occurrence and importance in the lives of the most malnourished makes this particular grain legume critical for lifting the nutritional baseline for many societies and many levels of those societies. In a sense, it is a fulcrum for leveraging Africa's basic nutrition. For all that, though, it is now not being intensively used to leverage the continental wellbeing. In this special sense, then, cowpea is being "lost," at least to future progress.

[1] These include peas, beans, peanut, soybean, chickpea and similar grams, lentil, and faba bean.

Although globally obscure, cowpea is grown by tens of millions of smallholders in Africa. In fact, it is estimated that 200 million children, women, and men live off the plant—consuming the seeds daily whenever available. Widely appreciated by the poor, cowpea seed is not only rich in protein but in oil and digestible carbohydrate too. (The Burpee Seed Company)

Regarded strictly from a botanical perspective, this crop seems strong enough to help lift Africa's food quality in the 21st century. The species is exceptionally rich in useful genetic diversity. It produces several different tasty foods. The plant is deep rooted, vigorous in growth, and reliable in production. It is both drought-tolerant and adapted to poor soils. The seeds are exceptionally nutritious, possessing protein (up to 24 percent in dry seeds) and a trove of other essential nutrients. As a dietary component, it complements the otherwise unbalanced diets the poorest sectors are forced to stomach. And, perhaps because of its African birth it beats out other legumes for performance on a variety of soils and an adversity of conditions found across this multiform continent. Indeed, cowpea has been called "a nearly perfect match for the African soil, weather, and people."

This crop originated as an inconspicuous little creeper among the rocks of the dusty southern Sahel and the bone-dry upper rim of central Africa. Africans living there thousands of years ago saved the best seeds they could

find and ultimately brought cowpea entirely under their care. Today, inter-pollinated descendants of their creations grow on millions of smallholder farms in a sweeping arc from Senegal eastward to Sudan and Somalia and southward to Zimbabwe, Botswana, and Mozambique.

In that great sweep, covering half of Subsaharan Africa, two hundred million children, women, and men live off the plant—consuming the grain daily whenever supplies make that possible. Widely appreciated by the poor, cowpea is not only rich in protein but in digestible carbohydrate too. Its energy content nearly equals that of cereal grains. In addition, the seed is low in antinutritional factors. And the seeds of select strains cook fast, an important consideration where fuelwood is scarce and expensive, as it is in that vast parched crescent of concern between Senegal and Mozambique.

One of the more remarkable and valuable things about this species is that certain of its cultivars mature with as little as 300 mm of rainfall. This makes it the grain legume of choice for the Sahelian zone and its contiguous savannas, both of which are population-dense, hungry, and vulnerable to outbreaks of malnutrition and mass misery.

No less remarkable is cowpea's value to the environment. The deep roots help stabilize the soil and the plant's shade and dense cover helps protect the ground and preserve moisture. Both these traits are of particular importance in the dry zones, where moisture is at a premium, soil is fragile, and wind a dirt-scouring demon. Like other legumes, cowpea fixes atmospheric nitrogen, thus lifting the nitrogen content in the land around it. It is often intercropped with sorghum, millet, or maize, as much to foster their good health as to furnish its own beans.

Beyond its value to the malnourished, this is a crop of high potential for rural development. Although Nigeria produces it by the millions of tons, production in East, Central and Southern Africa is still very low.

PROSPECTS

Because of its combination of benefits, cowpea is perhaps the most vital of all Africa's native vegetables. It seems thus likely that it has the best potential for boosting the nutrition of the greatest number of needful Africans. Even a small lift in cowpea performance can have a significant spillover benefiting millions[2] .

Within Africa

Humid Areas Prospects here seem moderate, but could rise quickly. In wet areas, cowpea falls victim to hosts of pests and diseases. Nonetheless,

[2] Such an initiative was begun by the long-standing USAID-funded Bean/Cowpea Collaborative Research Support Program, focused on research and training of scientists from Africa, Latin America, and the U.S. Information is available at isp.msu.edu/crsp.

types that flourish in moist savannas are coming available, and those could provide a solid foundation to build a better future.

Dry Areas Excellent. Cowpeas are more drought-tolerant than peanut or maize (but not more than millet), and are vitally important in the West African savanna, where the bulk of the crop is produced.

Upland Areas Variable, depending on location, but no less promising for all that. Most cowpea varieties do not withstand cold conditions that well. They either fail to germinate, grow slowly, or do not flower at all. Production in the highlands during hot, dry seasons can be very high however.

Beyond Africa

The dried seeds are eaten in parts of the Asian and American tropics and subtropics. They are, for example, well known in India, Brazil, the Caribbean, and United States, known there as blackeye peas. As better cultivars come available, cowpeas could become even more important in the dryland tropics. According to reports, cowpea is taking off in Thailand. China and a number of other nations seem ideal targets for future expansion. There, cowpea could contribute inexpensive protein to many predominantly starchy diets.

USES

Unlike other legumes, cowpea can be consumed at different stages in its development: fresh green leaves, dry leaves, green pods, green beans, or dry grain. The most popular—or at least most common—is the last.

Pods The immature seeds and the immature seed pods are boiled and eaten as a vegetable. This is a very special and highly promising usage. Indeed, we have dedicated a separate chapter to a cowpea variant called long bean, which developed far from Africa's shores and now deserves better back home.

Seeds Traditional West African cooking has found a variety of uses for this food. There, most cowpeas are cooked with vegetables, spices, and palm oil to produce a thick soup that accompanies the basic staple, notably cassava, yam, or plantain. The seeds are also decorticated, ground into a flour, mixed with chopped onion and spices, and pressed into cakes that are either deep-fried (akara balls) or steamed (moin-moin). Some are ground or crushed into meal that is used in buns, fritters, and sauces. Cowpea meal is also boiled, mashed, and served in puddings, porridges, and soups. The seeds are commonly boiled with maize, eaten as porridge, or even boiled in

their pods. Alternatively they may be steamed or fried to make a paste or sauce that is often eaten with ugali or other thick starchy staple. Canned cowpea has rapidly become popular in the Zimbabwean markets.

Forage In most locations cowpea is treated as a dual-purpose crop, in which one of the two products is hay. In years of poor rainfall, when stockfeed is scarce, it can be worth far more than the seeds. Livestock, particularly cattle, thrive on the stems and leaves left once the seeds have been harvested. Those haulms can also be dried, bundled, and stored away for the dry months when little else is around to keep domestic creatures happy and healthy.

Green Manure Cowpea fixes nitrogen efficiently, with amounts of up to 70 kilograms per hectare per year added to the soil. This makes it a useful living mulch for reconstructing broken-down land.

Other Uses Occasionally, cowpeas are roasted, ground, and served as a coffee substitute. In the United States, the green seeds are sometimes roasted to produce peanut-like snack foods.

NUTRITION

Dried cowpea seed is exceptionally nutritious, with up to 24-percent protein and 2 percent oil, with the remainder being carbohydrate, minerals, and lesser nutrients. This combination means that cowpea packs solid nutrition. On top of that it is palatable and relatively free of the kind of metabolites that suppress soybean's food value.

The protein itself is of good nutritional quality, consisting of 90 percent water-insoluble globulins and 10 percent water-soluble albumins. There is considerable genetic variation in amino-acid content, but lysine seems always in good supply. Indeed, that is one of the greatest features: combined with cereals in the diet, cowpea makes up for the lysine-poor cereals and roots. As in other grain legumes, methionine, cystine and tryptophan are deficient.

HORTICULTURE

Most of the crop is grown for home consumption. A portion comes from kitchen gardens or village compounds, but most cowpeas are grown in the main production fields as an intercrop with cereals and/or other crops such as tomato, okra, peppers, and eggplant.[3] In both dry- and moist savannas the cereal is millet, sorghum, or maize. This combination of legume and cereal

[3] Many men grow cowpea too. But most of them grow it as a sole crop and the grain they produce is more likely to be sold than consumed by the family. In this chapter we focus more on the subsistence production, whose growers are mainly women.

makes for a complex, dynamic, hard-to-manage system, but it meets the critical needs of growers, who above all must produce the family's yearlong subsistence. When the first rains appear, they typically plant the cereal together with an early-maturing cowpea (which is often destined for fodder rather than food). Once the cereal is growing well, a second cowpea crop is sown among the strengthening stems—a strategy used notably in the drier areas to avoid early season drought damage. Clambering types are considered best because they climb over and crush any weeds that try to interfere. Once the creeping cowpeas start moving out weeds are no worry.

Traditional cowpea types in the Sahel and savannas are attuned to subtle differences in the length of day. As if reading a calendar, they burst into flower just as the rainy season ends and the long period of dryness begins. That is a clever way to avoid devastation from pests and diseases, because vulnerable parts of the plant emerge after enemies have subsided. It is, however, a risky strategy because it puts the plants at the mercy of drought and blistering heat. Also, in this seemingly synergistic cultivation system, the crops compete for each other's light, nutrients, and moisture, which limits the capabilities of both. It the rains disappear too quickly, as occurs too often, the competition between cereal and cowpea can have catastrophic consequences on the quantity of food the family gets to eat that year.[4]

HARVESTING AND HANDLING

Depending on cultivar and climate, cowpeas may take as few as 60 or as many as 240 days to mature their seeds. Harvesting is complicated by the prolonged and uneven ripening characterizing many types. The pods must be harvested as soon as they mature because they shatter easily and after a few days wantonly scatter the seeds on the ground. Further, seeds that get damp from rain or excessive humidity before being harvested start sprouting inside the pods while yet on the plants.

LIMITATIONS

Under conditions of subsistence agriculture, the average yield of dry seed normally ranges between 100 and 300 kg per hectare. Compared to yields of modern soybean (3,000 kg per hectare and up), peanut (2,000), or even cowpea grown on experiment stations and in countries such as India (at least 2,000), this is an appalling level Much of the difference is due to the fact that cowpea occupies only a small part of each hectare of the mixed cropping system. But some is due to the particular types used by Africa's subsistence farmers. Those traditionally selected plants may be very clever at dodging their enemies but from a productivity standpoint, they aren't very good.

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[4] Over the past decades, there has been a steady decline in annual rainfall throughout the region. Therefore, growing two crops together increasingly requires compatible cultivars, more and more tolerant to drought.

Whatever the climate, locale, or cultivation method, insects are the major constraint. In the lowland tropics the effect can be so devastating that overcoming them could send grain production soaring 20 fold or more, according to literature reports. But it is not an easy task. Africa has at least 15 major and more than 100 minor insect pests that challenge cowpea.

By comparison with the insect onslaught, diseases are less troublesome, but that's not saying much. Fungi sometimes cause terrible damage, especially in the wetter areas. Devastating attacks are not unknown in the drier areas as well.

Even when the harvest is in hand, the farmer's fight for her food is far from over. Certain insects make their living on cowpeas in storage. Cowpea weevil and bruchid beetle are the major threat here. They begin infesting the plant in the field, but really capitalize when the seeds are crammed together in a grain bin or silo. There in weevil heaven each female produces 20 ravenous larvae every 3 or 4 weeks, so within a few months nearly every seed has a neat hole drilled in its side. And within six months little that is edible remains. Food prepared with even partially infested grain tastes bad, and selling seed exhibiting even a few of the telltale beetle holes is difficult. In Nigeria it has been estimated that some 30,000 tons of cowpea grain are lost annually, most of it during storage.

NEXT STEPS

Perhaps the quickest way to get cowpeas in Africa producing up to their fullest potential is to activate programs in Asia and the Americas. A global effort, involving say 20 nations from China to Chile and Australia to Arabia, could change the whole dynamic. This is not such an unlikely notion. Almost all nations face a long-term need for more drought-tolerant and more nutritious crops. In fact, cowpea is already rising slowly as a global resource. From this worldwide movement, the humanitarian benefit to the continent that produced the plant in the first place could be the greatest of all. But by developing new methods of production, new gene combinations, and new basic knowledge, all countries would be benefiting their own farmers and citizenry while building new momentum for a largely forgotten global crop.

So far, the main thrust of research for the cowpea-zone of Africa has been to induce farmers to grow the crop in pure stands rather than mixed with cereals. This is clearly a good thing if one considers only cowpea. But the subsistence farmers depend on the combination, and the switch to a single crop can reduce overall productivity. For small-scale farmers it may also weaken their security by taking away millet or sorghum, their most dependable crops. Nonetheless, for farmers with surplus land and labor, pure-stand cowpea makes an attractive cash crop. Researchers involved in it are not wasting their time. Some observers claim that such commercial production will never benefit enough cowpea growers to justify the research, but they could well be wrong. Cowpea has the potential to be a tool the

millions of impoverished farmers employ to lift themselves from poverty to prosperity. Given a chance to make a good profit they may embrace commercial cowpea with gusto.

Demand for cowpea fodder far exceeds current production, and a ready market exists for cowpea haulms, which can command nearly the same price as cowpea grain. Some emphasis should be put on this usage, even though feeding animals may seem a roundabout means for getting food to people. In this arena, cultivars primarily for fodder or green manure merit exploration.

Commercial Promotion The status of cowpea could be greatly lifted by stimulating demand through a sophisticated marketing campaign. Cowpea lends itself to this. It is a delicious food; it is grown, at least in Africa, organically without chemical inputs; it is a product that supports the poorest of African farmers; and it allows them to make a living from a hostile environment. Such a campaign could be targeted at local, regional, and international consumers (such as in Europe and North America). With bigger markets, research stations will fund more research, the private sector will finance product development, and the farmers of Africa will grow more cowpea and make a better living.

Food Technology The seeds have a relatively high protein content and it has been suggested that this could be extracted to prepare protein concentrates for the food manufacturing, textile and paper industries. In this regard, cowpea might end up Africa's counterpart of Asia's soybean…one of the world's top crops.

Combating the cowpea's enemies in storage is far from easy. Some progress is being made, however. In Nigeria it is recognized that harvesting promptly reduces the initial damage and that storage in the pod affords a degree of protection. Fumigation is effective, but difficult for small farmers to perform efficiently and safely. The hermetic storage of cowpeas in small granaries, silos and pits is being developed in Nigeria, where a very encouraging development has been the use of plastic liners in traditional dried-earth granaries. Investigations in Senegal have shown that cowpeas may be stored satisfactorily for up to a year in plastic sacks, albeit using as a fumigant the very toxic carbon tetrachloride. In India, the leaves of the neem tree are added to bins containing grains such as cowpea. Neem grows well in the cowpea zone of Africa, and this is another likely means for securing safe storage.[5] Cowpeas treated with palm, peanut or coconut oils are reported safe against insect infestation for as long as 6 months, but that affects the taste of some foods, and the seeds may lose their viability. Progress has been made, too, with breeding or selecting plants whose seeds resist bruchids, but

[5] For information on neem, see the companion volume *Neem: A Tree for Solving Global Problems*.

Kano, Nigeria. Cowpea is the grain legume of choice for the Sahelian zone and the contiguous savannas, both of which are densely populated, erratically dry, and vulnerable to mass outbreaks of malnutrition and misery. Its seeds provide quality protein and other essential nutrients that complement the otherwise unbalanced diets that the poorest sectors are forced to stomach. This farmer is growing a dual-purpose cowpea developed by International Institute of Tropical Agriculture and now being widely adopted by farmers as a crop to feed both humans and their animals. (B.B. Singh/IITA)

these seeds tend to be dark and thick-skinned, and that can make people resistant too.

Horticultural Development A dominant factor limiting seed yields is depredation by insects feeding off plants. Thrips are often most important, and these flower-eating scourges are so efficient that often no blossoms remain to form pods. Also slashing yields are pod borers that ream their way inside the pod and consume the soft contents before any seeds mature.

Controlling these pests seems a good topic for the methods and principles of integrated pest management. Already, it is known that destroying all diseased plant material in the field, employing mixed cropping system to reduce pest load, as well as rotating crops, helps lower insect depredations.

Fast-maturing cowpea types minimize the exposure to diseases (not to mention pests and even harsh weather), and are very desirable and important. However, the most effective long-term solution to the disease problems lies in the development of resistant cultivars. Research has already attempted this, but without producing breakthroughs big enough to cause the millions of subsistence farmers to switch.

The process of mixed-stand cultivation has fallen in and out of fashion with researchers in the region since the 1970s, without significant technologies resulting. Yet this is how African farmers grow cowpea, and it is begging for better understanding and support. The field layout is one feature for consideration.[6] The genetics of the plants is another. Farmers committed to the dual-cropping system with cereals and cowpea need daylength sensitive types that produce a flush of flowers after the cereal harvest. Breeding for every latitude and local preference would be a logistical and financial nightmare. But research aimed at improving plants for the main growing regions is well justified.

On a slightly different note, in Guinea cowpeas are being experimented with as a fallow crop in lowland rice fields. Initial results in 1999-2000 were said to be very promising with good yields, high levels of farmer interest, and noted contributions to soil fertility (which were the reasons for initiating the trials). This may introduce cowpea to a completely new, high potential environment, where it can make important contributions.

Storage The problem of insect infestation cannot be over-emphasized. One of our reviewers writes: "In Zimbabwe, we have tremendous difficulties with bruchids and must make sure crop gets from farmer to warehouse where it can be fumigated as soon as possible. It makes on farm storage and factory storage problematic." In this regard, an appropriate technology was developed at Michigan State University in the 1980s. Researchers discovered that simply turning the sack in which beans are stored is enough to virtually eliminate weevil damage. Weevils require upwards of 24 hrs to bore into a grain. During this time they need to brace themselves against neighboring grains in order to drill into their target. Turning the sack end-over-end 2-3 times once a day causes the weevils to loose their place, and require them to start afresh. After several aborted attempts the weevils die without having laid a single egg![7]

SPECIES INFORMATION

Botanical Name *Vigna unguiculata* (L.) Walp.

Synonyms *Vigna sinensis*, *Vigna sesquipedalis*

Family Leguminosae. Subfamily: Papilionoideae (Faboideae)—Pea family

Common Names (for grain types)

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[6] The standardization of row plantings—3 or 4 rows of cowpea to 1 or 2 rows of cereal, for example—has shown promise in trials, but is nowhere being widely applied by farmers.

[7] Information from Brent Simpson.

Arabic: Lupia (in Sudan)
English: cowpea, blackeye pea, blackeye bean, marble pea
French: niébé
Spanish: chicharo de vaca
Ethiopia: adanguari, nori
Nigeria: agwa, akidiani
Uganda: amuli, boo-ngor, omugobe, boo (in Acholi and Luo)
Zambia: ilanda, nyabo (in Tonga language)
Zimbabwe: nyemba (Shona) ndlubu (Ndebele, Zulu)
Botswana: dinawa, Nyeru or Dinawa (in Setswana)
Kenya: boo (in Luo language); kunde (in Swahili); thoroko (in Kikuyu)
Portuguese: ervihia de vaca
India: barbata, charla, Nindu pea, paythenkai, thattapayru (Tamil)
Sri Lanka: me-karak
Malaysia: kachang bol
Philippines: karkala, kibal
Thailand: tonkin pea
Mauritius: voehme (in Mauritian Creole)
Tanzania: kunde (in Swahili); nkunde (in Nyiha)
Lesotho: lLinaoa (in Sesotho)
South Africa: dinawa (in Northern Sotho)
Malawi: nkunde (in Tumbuka); khobwe (in Chewa)
Swaziland: tinhlumayi (in Siswati)
Seychelles: brenm (in Seychellois Creole)
Namibia: omakunde, olunya (white with black eye), omandume or ongoli (mixed black, brown, purple) (in Oshiwambo language, Ovambo tribe)

Description

Cowpeas are an annual crop. There are many different types, varying in growth habit from erect or semi-upright to spreading and climbing. They range in height (or length) from 20 to 200 cm, the latter being the climbing ones. The species is largely self-pollinating, but up to 2 percent outcrossing has been reported.[8] Flowers may be purple, pink, white, blue, or yellow. Pods tend to be long, smooth, cylindrical, and somewhat constricted between the seeds. Between 8 and 20 seeds occur per pod. They are globular to kidney-shaped, 5-12 mm long, smooth or wrinkled, and ranging in color from white, cream, or yellow to red, brown, or black, while some are speckled or blotched. The seeds are characteristic in having a marked white hilum surrounded by a dark ring. The most commonly grown are the white types or those with a black mark around the hilum, the latter being called

[8] Lush, W.M. 1979. Floral morphology of wild and cultivated cowpeas. *Economic Botany* 33:442-447.

'black-eyed.' Pods of most varieties hang downwards but in some they point sideways or upwards.

Distribution

Within Africa The leading cowpea growing countries are Nigeria and Niger, but the land area planted to the crop is substantial in Senegal, Mauritania, Mali, Burkina Faso, Côte D'Ivoire, Ghana, Benin, Togo, Chad, Cameroon, Central African Republic, Congo, Uganda, Tanzania, Sudan, Ethiopia, Kenya, Angola, Somalia, Zambia, Mozambique, Zimbabwe, Botswana, Namibia, South Africa, and Madagascar. Of total world production, about 80 percent comes from Nigeria, 80 percent of whose harvest comes from the parched northern states of Kano, Sokoto, and Borno.

Beyond Africa Cowpea is an important crop in some tropical American countries, especially in northeastern Brazil. In the USA, where "black eye peas" is a heritage crop, there is considerable cowpea production; California, Texas, Arkansas and the southeastern states yielding 20,000 tons a year. Most production is for the dry grain, but in the southeast it is grown primarily to serve the fresh and frozen market. It is also grown on a limited scale in the Mediterranean region and Australia. In India, the crop is grown especially for the immature pods and beans, fodder, and green manure. Indians enjoy cowpeas either boiled whole or mashed into dhal.

Related Species

Because of the large number of distinct forms and the fact that hybridization is readily achieved, there is much confusion and disagreement on the proper classification of the vast, spreading genepool of the crop called cowpea. All the forms are interfertile, can be crossed freely, and free gene flow is possible, and it now seems widely accepted that there should be no distinction at the species level. In other words, there is a single species *Vigna unguiculata*, with the other names as synonyms (and, often, subspecies). It seems probable that some, if not all, of the cultivated forms are in fact hybrids.

Nonetheless, the vast diversity selected by humans over thousands of years in this species has scarcely been tapped by modern science. There are myriad forms that could provide rewarding work to aspiring plant champions, and great benefits to humanity. One of these, the long bean (subspecies *sesquipedalis*), is highlighted in Chapter 12. A related species of *Vigna* (a genus of about 150 species) is the bambara bean (*V. subterranea*), discussed in Chapter 2.

6

DIKA

Throughout a vast swath of western tropical Africa, from Senegal to Angola, dika is a part of the diet. In the southwestern corner of its range, from Nigeria to Angola, the fruits are eaten. However, in the main area of occurrence, from Senegal to Uganda, the major food by far is the seed. Despite international obscurity, dika is hardly a minor resource. It provides food and income to rural communities in almost twenty countries. In several countries—Cameroon, Nigeria, Gabon, and Equatorial Guinea, for instance—it is one of the most widely sold of all forest products. Millions count on it for cash during the harvest season.

Throughout its native range the tree providing these valued fruits and seeds is among the most appreciated natural resources. When forests are cleared dikas are universally left untouched. Those treasured, multi-branched specimens topped by dense and often curving canopies of foliage are to be seen scattered through many secondary forests.

In season these companionable trees, which can grow as high as 40 m, become laden with green-and-yellow fruits that look like small mangoes. Depending on the species, the fruits vary between sweet and bitter.[1] Although the sweet version is mainly enjoyed fresh, it is also turned into jelly, jam, or "African-mango juice." There's even been an attempt to make dika wine—the result, so its maker claims, being compared in tastings to a Moselle Riesling.[2]

Seen in Africa-wide perspective, however, the fruit is a tiny resource compared to the seed. Each year harvesters gather "dika nuts" by the thousands of tons. The hard round balls, which look something like smooth walnuts, must be cracked open to get to the edible part. The kernels found inside have the texture normal to nuts and can be eaten raw or roasted like

[1] In recent years the two forms of this versatile plant have been proposed as separate species but acceptance has been incomplete. The "eating type," which yields good fresh fruits, retains the original name *Irvingia gabonensis*. The "cooking type," whose seeds are widely processed across West Africa, is called *Irvingia wombolu*. Harris, D.J. 1996. A revision of the Irvingiaceae in Africa. *Bull. Jard. Bot. Belg.* 65:143-196.

[2] The wine produced after 28 days of fermentation had 8.12 percent alcohol content. Akubor, P.I. 1996. The suitability of African bush mango juice for wine production. *Plant Foods Hum. Nutr.* 49:213-219.

cashews. Most, however, are processed. Some are pounded into dika butter, a product akin to peanut butter or almond paste. Some are compacted into blocks resembling chocolate (once called Gaboon chocolate). Many are pressed to squeeze out the oil that makes up more than half the kernel's weight.

In the main, though, the kernels are ground and combined with spices to form the key ingredient in "ogbono soup." This extremely popular special dish is a sort of unifying regional favorite (although every country fervently considers that it produces *the* best). Like okra and baobab leaves, this so-called dika bread provides the slippery texture so beloved in African soups, stews, and sauces. It also adds a sharp and spicy tang that is unforgettable.

Given the popularity of ogbono[3] soup, dika kernels are traded on both a local and a regional scale. All across western Africa they bring high prices, especially out of season. Even as far back as 1980 it was calculated that a farmer could make US$300 from the seeds gathered off a single dika tree.

Strongly flavored condiments such as dika are crucial to diets where staples are bland in the extreme. Sharp tasting soups, sauces, or stews add both flavor and nutritional balance to cereals, tubers, plantain, fufus, and doughs (cold gelatinous, warm glutinous, and steamed non-glutinous) that anchor the West African diet. Traditionally, these condiments contained local bushmeat, fish, leafy vegetables, dawadawa, dika, spices, or oils. In more recent years, however, foreign ingredients—including tomato, onion, garlic, chili pepper, black pepper, celery, and parsley—have begun making inroads. Even European processed products, including bouillon cubes and dehydrated soup mixes, are nowadays prime ingredients in traditional African sauces. Nonetheless, the original components—including dika, okra, egusi, sesame, spicy cedar, peanuts, oilbean seed, as well as an immense variety of leafy vegetables—still remain in common usage.

That continuing tradition is certainly surprising in the case of dika products, which are gathered individually by hand from scattered wild trees. Throughout history the notion of commercially cultivating this resource and creating an organized industry like that of, say, cashew has been inconceivable. Of the various hindrances, the biggest was the once-widespread belief that dika trees must be at least 10 or 15 years of age before they bear any fruits or nuts. For any large-scale operation requiring financial investment that was a killer condition.

Now, however, pioneers are opening a new future for this crop's wider use. Although still basically a wild species, dika can be said to be in the early stages of domestication. Advances now transforming its prospects include the recent availability of trees selected for kernel qualities such as shells that naturally crack open by themselves (like the commercial pistachio). Perhaps the greatest advance has been developments in

[3] Also spelled agbono. Another widely used common name is apon.

Dika fruits have traditionally been collected from wild trees in the forests, so not much has been reported about their likely ultimate contribution to food security. Nonetheless, harvesters gather dika nuts by the thousands of tons each year, and those kernels, if dried, can be stored for long periods. Through dika, millions of farmers already earn a critical income. They sell the fruit for juice, jam, jellies, and the fresh market. They sell the oil to factories making margarine, soap, or pharmaceuticals. The greatest profit center of all, however, is in the defatted kernel meal. (E.C.M. Fernandes, ecf3@cornell.edu)

vegetative propagation, allowing mass replication of such elite germplasm. Just as important, though, vegetative propagation slashes the delay in fruiting time; budded trees reportedly start producing fruits and seeds just two to four years after planting.

Those advances in knowledge are transforming the possibilities for this formerly scientifically obscure resource. Nigerian researcher J.C. Okafor for more than a decade developed horticultural techniques to facilitate commercial cultivation. In recent years, more and more researchers have begun to follow through with their own investigations. The International Centre for Research in Agroforestry (ICRAF, now the World Agroforestry Centre) chose dika as a priority species for African agroforestry.[4] Already, small experimental plantings have been established in Nigeria: at Iva Valley in Enugu and at Onne in River State. The latter was planted using marcots (air-layering plants), which flowered and fruited just 2-4 years after planting. Both Nigeria and Cameroon have even begun creating village-level nurseries where dika trees designated "superior" by local farmers are vegetatively propagated.

Although vast uncertainties still remain, no insurmountable barriers to this plant's complete domestication are known at this time. The coming years seem likely therefore to bring new life to the production of both nuts and fruits—making an agro-industry that is bigger, better organized, and more reliable than ever in dika history. Possibly, the added output will come from industrial-scale plantations. More likely, it will come from scattered village production as millions of farmers supplement and upgrade the trees they already possess. Dika moreover will be planted for shade, shelterbelts, beautification—along, for instance, streets in cities and highways in the countryside—thereby easing life in more ways than just the provision of food.

These activities are not just emanating from scientists flexing new-won knowledge. Among West and Central Africa's indigenous food plants, dika is high on the list of species the inhabitants hope to see developed. In a survey of five southern Cameroonian villages, for instance, dika was ranked top of the Ten-Most-Wanted-Tree list. Also, a report of farmer preference carried out in southern Nigeria showed that dika was top on the list of 5 preferred fruit trees.

Steamy zones such as southern Cameroon and eastern Nigeria represent one of the dika's special agronomic niches. Tropical lowlands are difficult to farm with modern agronomic approaches, and have consequently fallen behind the rest of the arable world. Dika, however, thrives in places such as the evergreen forests of Gabon, Equatorial Guinea, eastern Nigeria, and

[4] Atangana, A.R., V. Ukafor, P. Anegbeh, E. Asaah, Z. Tchoundjeu, J-M. Fondoun, M. Ndoumbe, and R.R.B. Leakey. 2002. Domestication of *Irvingia gabonensis*: 2. The selection of multiple traits for potential cultivars from Cameroon and Nigeria. *Agroforestry Systems* 55:221-229.

southern Cameroon, where magnificent primeval specimens can still be seen on all sides. This special adaptation to heat and humidity raises the possibility of improved dika plants being employed as an environmentally friendly cash crop for dense, moist, heavily shaded conditions. Communities around Enugu in southeast Nigeria planted dika extensively to control the menace of soil erosion. In the future, it might even help reduce the pressure on the ecosystem that worries so many of today's observers…the African rainforest.

Another important future possibility is the use of dika for lowering malnutrition. Although various oil-rich tropical seeds are being advanced to meet the hungry nations' escalating needs for food energy and protein, few (to our knowledge) are fostering dika for the purpose. Yet the kernel meal is high in oil and protein (including six of eight essential amino acids), and would make an exceptional tool for nutritional intervention in West and Central Africa where marasmus and kwashiorkor are the main baby killers.

Yet a third important possibility is its use as a cash crop. As a reward for hard work nothing succeeds like cash, and in this special regard dika is one of the most motivational of trees. Through it, millions of farmers already earn a critical income. They sell the fruit for juice, jam, jellies, and the fresh market. They sell the oil to factories making margarine, soap, or pharmaceuticals. The greatest profit center of all, however, is in the defatted kernel meal. This shelf-stable soup ingredient even has export potential. Indeed, entrepreneurial West Africans living in the United States already hawk molded ogbono cubes over the Internet.

Considered in overview, then, it can be said that although dika makes up a vital part of the traditional food system in much of West and Central Africa, its full potential has so far gone unharnessed. At this particular moment in history, however, the plant's imminent domestication is opening new opportunities for alleviating rural poverty and malnutrition, while at the same time promoting tree planting, diversifying land-use, and developing durable rainforest agroecosystems capable of superseding today's mindless exploitation.

The current handful of dika researchers are certainly enthused by the prospects their discoveries are unfolding. One calls the exploitation of dika a "win-win landuse strategy for Africa." He envisages a "Really Green Revolution" based on the diversification of agroecosystems with new perennial tree crops that reduce poverty, expand exports, and come close to sustainable agriculture. Dika is not the only species capable of transforming Africa's land use this way, but it is a leading candidate.

PROSPECTS

Given dika's special climatic adaptation and geographical occurrence, the prospects for enhancing its contributions seem good. But they are also limited by the tree's geographic demands.

Throughout a giant triangle from Senegal to Uganda to Angola dika is a part of the daily fare. Although this tree's fruits are eaten in some areas, the seed is the major resource. As a result, this so-far-undomesticated tree scores high on the list of species inhabitants hope to see developed. (Distribution after David Ladipo.)

Within Africa

Humid Areas Good. The real opportunities are in humid West/Central Africa, the area where the species is indigenous. A canopied jungle, however, is not its only habitat. This versatile tree also occurs naturally in gallery forest and semi-deciduous forest, where it stands in the open sunlight. Furthermore, it is often seen—usually standing alone—around the outskirts of towns or villages.

Dry Areas Poor. Dika is apparently restricted to fairly wet, well-drained, loamy-to-clay soils. Probably, it has little potential outside those warm, wet, fertile regions, but no one has tried to find out for sure.

Upland Areas Poor. Although dika seems to have no hope of thriving at altitude, trial plantings of individual trees might prove quite interesting.

Beyond Africa

It seems unlikely that dika will catch on as a food crop outside Africa. Nevertheless, the tree at-the-least would be an interesting one for long-term

plantings such as tropical botanical gardens to acquire and observe. Many now-highly productive trees of the humid tropics—rubber comes to mind—have only hit their stride outside their homelands.

USES

Although various parts of this species have their uses, not excluding the living tree itself, the seed is the resource upon which the crop's future overwhelmingly rests.

Fruits The fruits have traditionally been collected from wild trees for domestic use in the forests of the humid forest zone of southeastern Nigeria, Cameroon, Gabon, and both Congos. Despite the fact that they are routinely consumed in those countries, not much has been reported about their technical qualities.

Seeds If dried, the kernels can be stored for long periods. These dika nuts are usually ground into a smooth paste before use. Typically, that paste is mixed with hot water or slightly heated palm oil to create the unique flavoring that constitutes the essence of ogbono soup. When dropped in just a few minutes before serving, it also serves to thicken soups and stews, producing the viscous consistency consumers covet.

Oil The ground-up meal of dika nuts is commonly pressed to separate the oil. The glycerides in this yellowish liquid are made up largely of saturated fatty acids, notably myristic and lauric. The oil is used, as we've said, in soapmaking and cooking, and it has potential for pharmaceutical use as well.

Wood Dika wood is a local building material. It is a hard, heavy timber with fine grain. It is of minor overall economic value but the trade can be lucrative and exploitive.[5]

Medicinal Uses Dika products are used medicinally in most parts of tropical Africa. In Sierra Leone, for example, the Mende tribe uses the bark to relieve pain. The presence of an analgesic effect has been documented in experiments on mice.[6]

Other Uses The living tree serves as an ornamental as well as a shade tree for food, cash crops, and animals.

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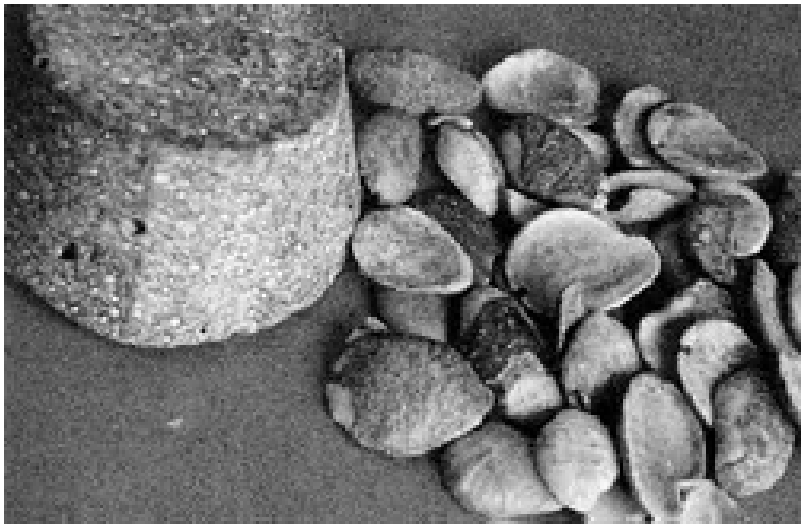
[5] The tree is categorized as "near threatened" on the Red List of Threatened Species maintained by the International Union for the Conservation of Nature (iucnredlist.org).

[6] Okolo, C.O., P.B. Johnson, E.M. Abdurahman, I. Abdu-Aguye, and I.M. Hussaini. 1995. Analgesic effect of *Irvingia gabonensis* stem bark extract. *Journal of Ethnopharmacology* 45(2):125-129.



Dika seed kernels (processed and unprocessed). These so-called "dika nuts," are widely traded in West Africa. They are something like cashews, can be eaten raw or roasted. Most, though, are ground and combined with spices to form the key ingredient in "ogbono soup," a spicy dish extremely popular among West Africans and Central Africans. This shelf-stable soup ingredient even has export potential. Indeed, entrepreneurial West Africans living in the United States are already hawking molded ogbono cubes over the Internet. (R.R.B. Leakey)

NUTRITION

The fruits' popularity is largely due to its sweet-and-sour flavor combination. The sugar content of juice has been found comparable to pineapples and oranges, with even more vitamin C than the latter.[7]

In one set of measurements, the kernels contained about 60 percent oil, 30 percent total carbohydrate, 3 percent ash, 8 percent crude protein, 1 percent crude fiber, plus 10 mg vitamin C per 100 g.[8] Reportedly, it is also rich in beta-carotenes.[9]

Although such high oil content gives remarkable food-energy values, other reports have quoted oil contents up to and beyond 70 percent.[10]

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[7] Akubor, 1996, op. cit.

[8] The figures are calculated on a dry weight basis. The kernels measured were those of *Irvingia wombolu*. Ejiofor, M.A.N., S.N. Onwubuke, and J.C. Okafor. 1987. Developing improved methods of processing and utilization of kernels of *Irvingia gabonensis* (var. *gabonensis* and var. *excelsa*). *Int Tree Crops J.* 4(4):283-290.

[9] Obioma U. Njoku, L. and J. Obeta Ugwuanyi. 1998. Nutritional and toxicological properties of Dika fat (*Irvingia gabonensis*). *J. of Herbs, Spices & Medicinal Plants* 4(4):53-58

[10] Leakey, R.R.B. 1999. Potential for novel food products from agroforestry trees: a

According to one report the oil was made up of 39 percent myristic acid and 51 percent lauric acid.[11] Such saturated fats may not be the Western World's ideal in edible oil but they still merit recognition in hungry nations with high levels of marasmus, the form of malnutrition deriving from too few calories.

The amino acids in these seed kernels are reasonably balanced for human nutrition. In one test, lysine, tryptophan, valine, threonine, isoleucine, and phenylalanine were the essential amino acids whose levels compared favorably with the FAO/WHO provisional pattern for proper nutrition. Methionine and cysteine were deficient, and were the first limiting amino acids.[12]

In addition to food energy and quality protein, the seed could be a potential source of potassium, calcium, and phosphorus. The levels of iron, zinc, copper, and manganese are said to be low, but their levels probably depend on the local soil. The total oxalates are low when compared with other vegetables, so these antinutritional factors are unlikely to interfere.

The kernel's food-thickening property is thought to be due to mucilaginous polysaccharides that become more viscous with cooking. This unusual characteristic has been called "drawability."

HORTICULTURE

Horticulturally speaking, dika suffers from the fact that it has never been a managed crop. Nevertheless, it seems likely to respond to conventional horticultural practices. As far as field cultivation is concerned, it is known that the growth from seeds is slow. In addition, unless the seeds are handled carefully, most fail to germinate. According to one recent report, drying the seeds slowly under ambient conditions and subsequently soaking them for a day gives 100 percent germination.[13] And it has been found that certain seeds certainly don't require 10 or 15 years to fruit. In trials many trees flowered in about a third that time—not so different from apple and most orchard crops.[14]

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review. *Food Chemistry* 66:1-14.

[11] The seed was from Cameroon. Unpublished data from Hellyer in Leakey, ibid.

[12] Eyo, E. S. and H. Abel. 1979. Untersuchungen zur Fettsaurenzusammensetzung der Samen von *Irvingia gabonensis*, *Cucumeropsis manni* und *Mucuna sloanei* aus Nigeria ("Investigations on the fatty acid patterns of the seeds of *Irvinga gabonensis*, *Cucumeropsis manni*, and *Mucuna sloanei* from Nigeria."). *Der Tropenlandwirte* 80:7-13.

[13] Omokaro DN; Nkang A; Nya PJ. 1999. *Seed Science and Technology*, 27: 3, 877-884. The seeds were dried for 72-84 hours and then rehydrated for 24 hours. Within 33 days all of them had germinated.

[14] Ladipo and Anegbeh, 1995, reported in Ladipo, D.O., J.M. Fondoun, and N. Ganga. 1996. Domestication of the bush mango (*Irvingia* spp.): some exploitable intraspecific variations in west and central Africa. In *Domestication and commercialization of non-timber forest products in agroforestry systems*. Non-Wood Forest Products 9. FAO, Rome (available on-line via fao.org/documents).

It is known, also, that grafting, budding, air-layering, marcotting, and cuttings are all feasible, at least when applied on young wood. In addition, it has been discovered that many dika trees on Cameroonian farms had arisen from transplanted wildlings.

HARVESTING AND HANDLING

As far as best practices for handling, not much is reported. One study showed that fruits harvested at the mature green stage and ripened at 26-29°C were preferred to the naturally tree-ripened fruits in color and texture, although their overall composition remained unchanged.[15]

LIMITATIONS

The complexities of such things as flowering and fruiting are little understood. Anyone endeavoring to manage a dika plantation will be a true pioneer. In any such effort it is crucial to start with plants possessing the genetic capacity to produce well. In this regard, researchers at Onne in southeast Nigeria, have found that different trees demonstrate vast variation. For example, in 1995 one young tree produced only 18 fruits while its neighbor yielded 207.[16]

To extract the kernels the shells are currently broken open by hand. Different countries favor different techniques. Some extract the seeds from the fresh fruits as practiced by fruit collectors at Enugu. Others ferment the fruits and extract the kernels wet, while yet others ferment and sun-dry the seeds before cracking open the hard, dry shells. All these methods are problematic. The whole operation is exceptionally tedious and absorbs untold proportions of the villagers' lives.

NEXT STEPS

What could the world do to advance dika? Almost everything. Examples follow.

Extension Support With no extension support for dika farmers, anyone possessing a tree is on her own. One simple thing that could help such worthy souls is capacity-building specifically for their needs. This might involve practical training to pass on the techniques and requirements for successful cultivation. It might also involve demonstration plots where farmers can see and learn how the tree is best treated. And it might even include incentives to small farmers.

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[15] Fruits held at 12-15°C developed symptoms of chilling injury. Joseph, J.K., and O.C. Aworh. 1991. Composition, sensory quality and respiration during ripening and storage of edible wild mango (*Irvingia gabonensis*). *Int. J. Food Sci. Tech.* 26:337-342.
[16] Ladipo, 1996, op. cit.

In a related effort, green-fingered individuals should set up elite germplasm plots and sell or supply grafted plants to villagers. The current "superior" germplasm currently being evaluated may help to improve farmers' welfare if it is a big improvement over the average dika material today's farmers rely upon.

In general, then, emphasis should be placed on the mass production of planting materials using vegetative propagation and skilled professionals.

Document Cultural Traditions It is reported that the Baka of the Dja Forest (Cameroon) and the Ibos of southeast Nigeria have a wealth of insight into their local dika trees. Other peoples certainly have knowledge to share as well. The opportunity to tap the experience of farmers who have lived their lives with dika should not be missed.

Horticultural Development As already noted, vegetative propagation is the key to the process. Currently, studies are in progress in Nigeria and Cameroon to improve dika air layering, grafting and budding, all of which are means of propagating from the mature crowns of selected trees. The use of cuttings would be an especially attractive alternative as it avoids graft incompatibilities and potentially can produce large numbers of trees. Simple, low technology methods have been developed for juvenile shoots,[17] but getting successful cuttings from mature shoots is still an unsolved challenge.

Desirable improvement objectives include increasing fruit size, improving the taste of fruits, increasing yield, and reducing tree height and the time to bear fruits. It is already clear that dika trees vary hugely in fruit and kernel traits. It is also already clear that the potential for selecting trees with superior characteristics is great. These elite specimens are candidates for vegetative propagation. Finding them across thousands of kilometers of difficult terrain is the problem, but it is a far-from-insoluble one.

Already a few germplasm collections have been made. In Nigeria, for instance, genebanks have been established at Ibadan (in collaboration with the National Centre for Genetic Resources and Biotechnology) and Onne (in collaboration with the International Institute of Tropical Agriculture, IITA). In Cameroon a dika genebank has been established at M'Balmayo (in collaboration with the Institut de Recherche Agronomique pour le Développement). More should be set up in Congo, Gabon, Côte d'Ivoire, and so forth.

The existing collections, together with observations on field-grown trees, have already revealed individual specimens that could promote rapid progress towards domestication. These unusually promising variants include:

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[17] Shiembo P.N., A.C. Newton, and R.R.B. Leakey. 1996. Vegetative propagation of *Irvingia gabonensis*, a West African fruit tree. *Forest Ecology and Management* 87:185–192.

Collecting dika germplasm in Southeast Nigeria. The tree thrives in tropical Africa, and its special adaptation to heat and humidity raises the possibility of improved forms being employed as an eco-friendly crop for dense, moist, heavily shaded conditions. Also, dika holds promise as a crop for controlling soil erosion. Thus, it could be used to benefit the ecosystem whose future so many worry about today: the African rainforest. Here, two (female) students and two farmer volunteers show off the results of a day's search. (Paul Anegbeh)

- *Multiple Bearing* In several countries dikas that flower and fruit several times in a year have been observed. Among the 182 trees planted in 1990 at the IITA Station in Onne, Nigeria, for example, a few flower two, three, or even four times annually.
- *Precocity* Some seeds produce plants that start fruiting at a far younger age than expected. Of the trees mentioned above, about half flowered within five years. Some even set fruit twice a year by then.[18]
- *Good Form* Branching and tree form can be key to a successful orchard in fruit and nut trees. Dwarfing is an especially valued trait because it greatly simplifies the harvest. So far, dwarfs have not been found or created (by grafting, for instance), but have been developed by marcoting.
- *Split Fruits* During 1995 dika collections in the north of Gabon, a tree was found whose nuts split open naturally. When its fruits were spread out to dry, 93 percent had split open after 72 hours; none of the seeds from six other Gabonese dika trees had split at all.[19]

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[18] The seeds were planted in 1990. By 1994, 83 of the trees (45 percent) were flowering; by 1995, 100 (55 percent) were flowering.
[19] D. Boland, ICRAF. This remarkable tree was discovered on a farm near the town of Bibas. The scientists named it G28. Seed samples have been planted in the dika

- *Color* On a typical dika, the young leaves are pale green although some can be pink. But on a few trees the leaves remain red even when mature. This phenomenon apparently occurs only in the fruit-type species (*Irvingia gabonensis*). This quality could presumably be captured by vegetative propagation. Rosy-leaved dika trees might have potential for amenity plantings throughout western Africa, if not the whole tropics.

Plantation Trials The germplasm and knowledge already assembled indicates that dika domestication can enhance the human nutrition, natural environment, and local economy of the places where the species occurs. For the present we hesitate to recommend full-scale commercial plantings, but now is certainly the time to continue establishing ever-more sizable trials on research stations and on farms to test performance of the best genetic stock currently available. Also, it is not too soon to start large-scale demonstration trials in the right rural areas.

Expanding Markets Governments, good-will organizations, and activated individuals need to pool their efforts to increase and regularize the wider use of dika products. This should help rural people, rural economies, and rural environments. Even now many Africans depend on dika and other non-timber forest products for their livelihood. In a survey made in Cameroon's humid forest zone, sales of the four main non-wood native forest products[20] amounted to at least US$1.75 million in the first half of 1995. More than 1,100 traders, mainly women, were engaged in distributing the wild-tree products. Furthermore, the traders reaped a 30 percent mark up on each sale. But in the future even more Africans could benefit. The potential for expanding production and trade are good. Contrary to international belief, this sustainable use of living trees is not a dying business. Increased urbanisation is actually encouraging market expansion, as transplanted countryfolk living in the cities pine for the tastes of home.

Dika nut may also find a market beyond Africa. Indeed, it is a good candidate for "green marketing" in places such as Europe and North America. Exporting dika products such as thickening agents, oil, ogbono soup cubes, and the rest will provide incentive for West and Central African farmers to diversify and control quality. This will generate income for subsistence farmers, and create export revenues for countries in desperate need of them.

Quality Control Most non-wood forest products are still collected and marketed informally, with little organized oversight. The result is an

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genebanks at Onne (Nigeria) and M'Balmayo (Cameroon).

[20] In order of importance, the four were butterfruit (*Dacryodes edulis*), dika, abata cola (*Cola acuminata*), and erimado (*Ricinodendron heudelotii*). Butterfruit is featured in the companion volume on Africa's fruits.

unreliable resource. Now is the time to introduce various safeguards, performance standards, and a pricing system reflective of quality. Farmers will then strive to reap the reward of greater profit. The result will be superior products, a reliable resource, and better off farmers.

In southern Nigeria, where ogbono is consumed extensively, various growers, wholesalers, and consumers have already begun the process of upgrading the supply. They've proposed quality classes for dika kernels, ranging from Grade A (the top) to Grade D. To encourage the further use of dika-kernel oil, a quality standard for pharmaceutical grade oil has also been proposed.

Protection Although the species is still relatively common and widespread, many wild stands are in decline owing notably to pressures from logging and human settlement, as well as to the plant's reluctance to regenerate. Various animals, including elephants and lowland gorillas, love the mango-like fruits and disperse the seeds. But without those creatures the species apparently has difficulty regenerating. In certain regions of Côte d'Ivoire, for instance, people replanting dika seed around their village are the only ones sustaining this age-old resource.

What anyone could do about this is not so clear, but a few possibilities come to mind. For one, across the species' range the destruction of these exceptionally useful trees, which provide food and income for up to a century, should be minimized. For another, the few locations where dika diversity is especially high should be conserved. And the replanting of dika trees should be everywhere encouraged.

Food Technology Food technology could do wonders for the dika business, and it provides a powerful way to open new markets. Among the most crucial needs is a nut-cracking device.

One special use for processed dika may be as a generalized food thickener. Indeed, a polysaccharide chemist could well have a field day exploring the ingredients and properties of this barely studied material. Dika nut meal reportedly absorbs water and fat better than raw soymeal does, and "hence may have useful applications in processed foods, such as bakery products and minced meat formations."[21]

The kernel's food-thickening property is, as previously noted, thought to be due to mucilagenous polysaccharides that increase viscosity with heat. This characteristic "drawability" is an important trait for genetic selection, and through its development food technologists could provide exceptional input into the dika-domestication activities. Without that input, the plant-domestication efforts may create magnificent trees whose seeds are spurned

[21] Giami, S.Y., V.I. Okonkwo, and M.O. Akusu. 1994. Chemical composition and functional properties of raw, heat-treated and partially proteolysed wild mango (*Irvingia gabonensis*) seed flour. *Food Chem.* 49(3):237-243.

by consumers because they just don't make an ogbono soup that is slippery enough on the palate.

Nutrition For a food as widely used as this one, there is an perplexing lack of nutritional information. Not only are rheological analyses needed, but chemical, biochemical, and nutritional trials should be run in both laboratories and clinics.

SPECIES INFORMATION

Botanical Name *Irvingia gabonensis* (Engl.) Engl. and *Irvingia wombolu* Vermoesen.

Synonyms There are many, such as *Mangifera gabonensis* Aubry-Lecomte ex O'Rorke, but in practice both species are field-recognized as *Irvingia gabonensis*. Formerly, the sweeter form was considered to be *Irvingia gabonensis* var *gabonensis*; the bitter form (now *Irvingia wombolu*) was *Irvingia gabonensis* var *excelsa*.[22]

Family Irvingiaceae (also placed in Simaroubaceae)

Common Names

English: bush mango, wild mango, dika, dika nut
French: manguier sauvage, chocolatier
Hausa: Agbalo
Nigeria: oro, oba, abesebuo, goron biri, oro, moupiki, muiba, eniok, andok,
Ibo: ogbono (kernels)
Afemai (Edo): ikpe (*I. wombolu*); ogi (fruit of *I. gabonensis*)
Yoruba: apon
Sierra Leone: bobo
Côte d'Ivoire: boboru, wanini
Cameroon: andok
Batanga (language in prime dika country near Kribi, Cameroon): mbumbwe'bo, nja'a
Congo: meba, mueba

Description

The dika is a deciduous tree reaching heights of 30 to 40 m. The bole, usually straight and cylindrical, is covered by a scaly gray bark that flakes away in plates. The trunk is typically short and slightly buttressed, with a

[22] The binomial comes with various "authorities," such as *Irvingia gabonensis* (O'Rorke) Baillon and *Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baillon.

diameter of 1 m and more. The smooth leathery leaves are attached to the stem alternately. The flowers are greenish yellow, as are the open-pollinated, mango-like fruits.

The heartwood is pale-green, brown, or orange yellow, fading on exposure to a gray brown. Sometimes, it develops dark gray streaks. The sapwood is lighter, but is not always differentiated. In woodworking terms, the texture is fine to medium, the grain straight to interlocked, and the surface is without luster.

Distribution

Within Africa Dika is found in the western and central tropics, from southern Senegal to the northern tip of Angola (notably Cabinda), including Congo, DR Congo, Nigeria, Príncipe, Ghana, Côte d'Ivoire, Guinea, Sierra Leone, Sudan, and western Uganda. It is often found near riverbanks and reaches optimal growth in the dense evergreen rainforest.

Beyond Africa The tree is apparently unknown outside the African continent.

Horticultural Varieties

No named varieties are yet in commercial use.

Environmental Requirements

The outer limits of its cultivation are unknown, and whether the present occurrence is truly representative is uncertain.

Rainfall Although the tree probably cannot survive drought, it is generally unaffected by heavy rainfall (so long as the soil does not become waterlogged). It performs well at Onne, Nigeria with an average of 2400 mm of rainfall annually.

Altitude This is exclusively a lowland species, but whether that is a genetic imperative is uncertain.

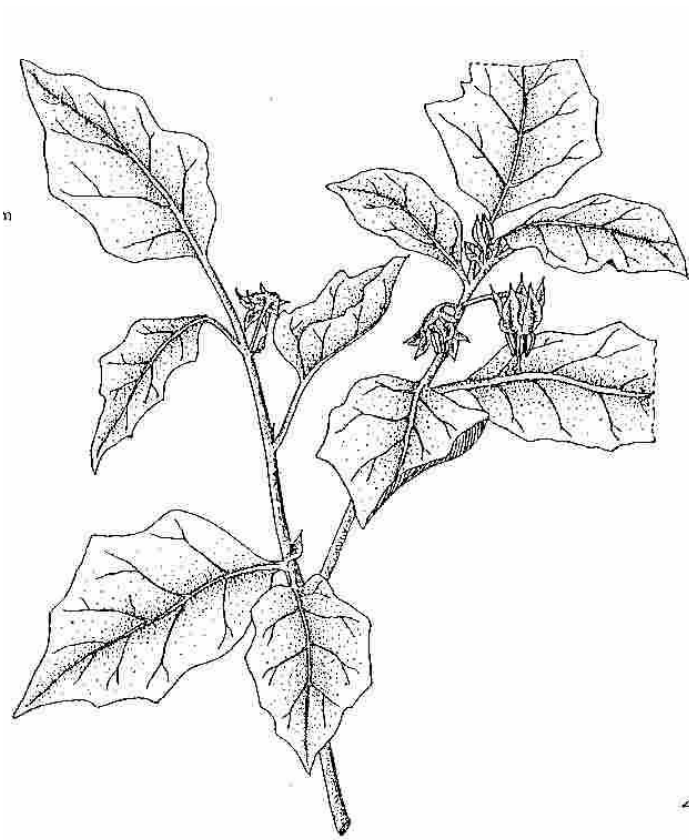
Low Temperature Dika trees probably cannot take freezing weather and even temperatures that approach freezing may damage them, although in the absense of any trial of cold conditions that is speculation.

High Temperature Given the tree's native habitat, it seems safe to say that it can withstand warmth.

Soil As earlier reported, dika occurs in fairly wet, well-drained, loamy-to-clay soils. The assumption for now is that it is restricted to such sites.

Related Species

In Southeast Asia a few dika cousins can be found. Mainly, they are renowned as prime candidates for high-priced tropical timbers. But one, *Irvingia malayana* Oliver ex Bennett, is the source of a vegetable oil called "cay-cay fat." In Nigeria are found two other species, *Irvingia smittii* Hook.f. and *Irvingia grandifolia* (Engl.) Engl, the latter used as timber.



7

EGGPLANT (GARDEN EGG)

Late in the 1500s British traders introduced London's greengrocers to a strange new vegetable they'd picked up along the coast of West Africa. By 1587 this so-called "Guinea squash" was on English dinner tables. Although eaten as a vegetable, it was actually a small fruit about the size of a hen's egg. It was the same color as a hen's egg also. This pure white ellipsoid made an eye-catching eatable, which for obvious reasons the public soon dubbed "egg-plant."

At roughly the same time another vegetable also appeared in Britain. This one had fruits nothing like eggs. They were much larger, deep purple in color, and irregularly misshapen. For all their differences, though, the two plants were botanically related and shared common culinary characteristics.

For a while both were used. Eventually, however, the Guinea squash lost its toehold, and fell out of Western cuisine. The newcomer, on the other hand, not only survived but also took over its predecessor's felicitous name. This is how a purplish blob, looking like no egg seen since perhaps the dinosaurs, came to be misnamed "eggplant." The interloper[1] that stole an African plant's good name hailed from Asia, where it has been cultivated more than 4,000 years. In the Far East it even now holds a position comparable to that of tomato in other parts of the world. Indeed, it is sometimes referred to as "Asia's tomato."[2]

In recent centuries this versatile purplish vegetable has gone global in a big way and is now part of virtually every cuisine. It is fried, grilled, roasted, boiled, seared, baked, steamed, mashed, pickled, stir-fried, pureed, and otherwise prepared by many peoples. To give just a smattering of examples: Greeks, Italians, Syrians, and Egyptians all feature eggplant as daily fare. However, in the love of this bland and humble food none surpass the Turks, who claim to know a thousand ways of preparing it.[3]

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[1] *Solanum melongena*. Also known as brinjal or aubergine.
[2] China and Southeast Asia together contribute 78 percent of world production, and in Japan eggplant is the fourth-most-important vegetable, after sweet potato, radish and Chinese cabbage.
[3] Turkey actually grows about 20 percent of the world's production—more than the rest of Europe combined.

This worldwide popularity is something of a mystery. Lacking in nutritional quality, high monetary return, or even flavor, the eggplant has in some strange way insinuated itself into myriad local specialties. Indeed, it is the heart of famed national dishes, including: moussaka,[4] baba ghanoush,[5] ratatouille,[6] and Imam bayaldi.[7] And Sicilians, who certainly know a thing or two about fine dining, rave over caponata.[8]

Because of the general trend toward ever-greater reliance on vegetables and on diversity in diets, the enigmatic eggplant is growing in global popularity faster than ever. Already, it has taken firm hold as a meat substitute. Popular vegetarian dishes now include such things as eggplant Parmesan, eggplant lasagna, eggplant curry, and even eggplant chili. The vegetable also lends splashes of purple to trendy modern sautés, ragouts, pizzas, or vegetable Napoleons.[9] It has even become big in the self-styled capital of cuisine: New Orleans.[10]

While this culinary juggernaut commandeered the world of cuisine, the original eggplant—the Guinea squash—was left to languish. Four centuries later it remains unknown to the West and to modern horticultural science. Yet it too possesses an array of gastronomically interesting qualities. It, too, could be a globetrotter, not to mention a much bigger contributor to Africa's own food supply.

Although used like its Asian cousin, Africa's eggplant is quite different in appearance. Most of its fruits are sized and shaped like eggs. Indeed, many are reminiscent of a pointy tomato, a species to which they are so closely related that they can be considered Africa's answer to South America's tomato.

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[4] Among the Greeks' many eggplant recipes, moussaka is the most famous. It's basically an older version of Italian lasagna, with eggplant slices subbing for layers of flat pasta. It typically includes ground lamb, onions, and pungent-sweet spicing.

[5] Eggplant, roasted in an oven or barbecue grill, is the basis of Greek and Middle Eastern dips and spreads. Baba gannoush (also spelled gannouj) is best known.

[6] A famous French dish from Provence, ratatouille is a kind of vegetable casserole, in which each vegetable is cooked separately to its own specifications then turned into a luscious melange.

[7] Imam bayaldi, a mashed-eggplant dish, is named after the legendary moment in the 16th century when a religious man waited to taste a sample being served by a beautiful woman. As she bent over to present the plate, the veil slipped from her face. Imam bayaldi means "the leader has fainted."

[8] Caponata is an eggplant relish with a tantalizing sweet and sour flavor. It may be spread on pasta or on bread and eaten as a sandwich. It is also served with meat, poultry, or fish.

[9] Napoleons are layered foods, best known as desserts or pastries. In this case, the cook starts with a round of eggplant and tops it with slices of such things as zucchini, onions, peppers, mushrooms and dried tomatoes and cheese. The resulting pile is then baked.

[10] "We do like eggplant here in New Orleans," writes a local journalist. "We chop it and saute it, batter it and fry it, mash it and season it, stuff it with meat, seafood, oregano, breadcrumbs and itself. Oh yes, some chefs these days even turn it into soup, often with coconut milk to remind us where the stuff actually comes from."

The brightly colored fruits known as garden eggs are a significant vegetable resource almost Africawide. The crop is high yielding, easy to grow, and simple to harvest and handle. It is integral to many cuisines, cultures, and economies. Yet in many parts of Africa there is considerable scope for producing much better varieties in much better quantities. (G.W.M. Barendse)

This is among the most appealing vegetables the eye can see. Few others boast such rich colors. Among Africa's overall eggplant diversity it is possible to find fruits in white, cream, yellow, green, lime, orange, pink, red, plum, burgundy, lavender, violet, purple, or dusky black. Many come striped and multi-colored. And all possess a glossy skin that tends to shimmer in the sunlight. Beyond being egg-shaped, they can be also round, flat, ribbed, and pumpkin-like. Some get to be as imposing as beefy tomatoes; in general, though, they closely emulate chicken or duck eggs in size. Most start out white, and are normally eaten before exposing any hint of the final color they will ripen into.

Because the taxonomy of the different African eggplants is too complex and uncertain to bother with here, we have chosen to highlight a single

species, *Solanum aethiopicum*. In fact, we highlight only one of the four groups recently identified within that species (although much of what is said applies to all African eggplants). In English, fruits of this so-called Gilo Group go by names such as scarlet eggplant, mock tomato, garden egg, garden huckleberry, or gilo. They are the most widespread eggplants cultivated in Africa, and can be found from southern Senegal to Nigeria, from Central Africa across to eastern Africa, and from Central Africa south to Angola, Zimbabwe, and Mozambique. And they are almost certainly the original "Guinea squash" Londoners were admiring 500 years ago.

Many gilo cultivars have fruits that are delicious raw—both when immature *and* fully ripe. They can be chewed, sliced, or pureed into juice and eaten fresh like tomatoes. Depending on type, some are sweet, others bitter (a feature many Africans prefer in a vegetable). At a glance, those in the know can distinguish the sweet cultivars, whose fruits possess smoother skin and a more evenly rounded profile.

Despite international obscurity, this is a resource of considerable economic importance. Throughout Africa local garden eggs are very popular and play an important part in many diets. They have a long storage life (up to three months) and transport well. They are also often dried for use later in the agricultural cycle when fresh foods are unavailable. They (as well as the leaves of some cultivars) provide a reliable and continuing source of income for millions of farmers, most of them women. In rural districts from Senegal to Mozambique, a common sight is women hefting baskets of garden eggs on their heads to sell in nearby villages or townships. The crop is mostly grown, harvested, and marketed close to home, and it forms a crucial part of both the rural economy and the female existence.

The plants are notable for yielding a lot from a little space. They can produce a profit from the tiniest plots; even a few plants grown in garden pots can provide a worthwhile harvest. The plants are easy to raise, relatively free of disease and pests, and provide a steady supply of both food and income.

Like their famous Asian cousin, these vegetables seem at first sight to be hardly worth attention. They are mild in flavor and not especially nutritious. And they certainly don't light up the meal on the dinner plate—once cooked they usually end up a brown and squishy mass.[11]

Clearly, though, this country cousin of a booming global resource should not be left languishing in the scientific wilderness. Because it remains largely unsupported by research, it nowadays falls far short of its potential. At present only a handful of researchers are championing its cause, but this small group is enthusiastic about the crop's promise. Given attention, they say, Africa's own eggplant could achieve a very big future. And they are

[11] This is also true of the best-known eggplant, which similarly discolors upon contact with the air. "Eggplant pulp will, upon cooking, turn a murky shade of brown and the consistency of mush," a food writer explained in the *Washington Post* newspaper.

right: In this neglected vegetable there is a whole new world of colors, textures, flavors, and culinary uses to explore and exploit. If the common eggplant provides any guide, the African counterpart offers a foundation for myriad flavors, textures, and ingredients in meals celebrating dozens of local traditions, cultures, and food combinations.

Why should Africa invest time and effort on these crops? Beyond the reasons referred to above lie further justifications. The plants, for example, are very adaptable and can be grown in widely different climates. They are fast maturing and yet can be harvested over a period of time, so they yield both quick results and extended ones. They could notably benefit soil conservation activities, especially when used to quickly cover bare soil in the spaces between the farm's main crops. They tend to tolerate shade and so can be fitted in around various taller plants, such as bananas, cassava, and trees.[12] They are suited to infertile sites and benefit various difficult soils, and are likely candidates for wringing income from numerous kinds of "agricultural wastelands."

Because of their partiality for small spaces, this is a crop for city gardens squeezed in among the structures of modern life: high-rise buildings, factories, shanties, roads, train tracks, and chain-link fences. This is already apparent in African cities. A survey in Dar es Salaam, for example, found that the most frequently grown non-leafy vegetables were (in order of importance): tomato, common eggplant, African eggplant, sweet pepper, hot pepper, okra, cucumber, and carrot.[13]

To sum up: The local garden eggs are significant vegetable resources almost Africawide. They are good for nutrition, rural income, and soils. They are high yielding, easy to grow, and simple to harvest and handle. They are vital to local cuisines, local economies, and local cultures. They have untapped potential waiting to be brought out by research. In many parts of Africa there is considerable scope for producing much better varieties in much better quantity. They also have notable market potential and could become the cornerstone of localized rural economic development. And there is even potential for exporting African eggfruits to Europe and North America and earning some hard currency.[14]

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[12] One study (in Java, where these African eggplants are known) showed that 35-60 percent shade does not affect the edible yield of the species.

[13] The authors found that the leafy vegetables being most commonly cultivated in Dar es Salaam were: leaf amaranths, sweet potato leaves, pumpkin leaves, cassava leaves, cowpea leaves, Swiss chard, chinese cabbage, African kale (*Brassica oleracea* var. *acephala*), and nightshade (*Solanum scabrum*). Leaf amaranth is dealt with in Chapter 1; okra in Chapter 16.

[14] Caribbean nations already export African eggfruits to Europe under their local name "anthora."

Yeji market, Ghana. Throughout Africa local garden eggs provide a continuing source of income for farmers. In rural districts from Senegal to Mozambique women are commonly seen hefting baskets of them on their heads to sell in nearby villages or townships. Yet these vegetables have untapped commercial promise and could become the cornerstone of localized rural economic development. (FAO photo/P. Cenini)

PROSPECTS

The years ahead will likely see this become a rising star of the vegetable kingdom.

Within Africa

Humid Areas Excellent. The African eggplant species are generally resistant to the molds, mildews, and other fungal scourges that achieve their greatest development in the lowland tropics' heat and humidity. According to reports, they even show resistance against some of the worst soil-borne plant pathogens—including *Fusarium oxysporum* and *Verticillium dahliae*—and may have potential as tools to avoid soil sickness (see later).

Dry Areas Good. These plants are moderately drought resistant, and with them irrigation is rarely needed. The exact level of drought tolerance is untested, but African eggplant is known to survive dryness better than the Asian counterpart.

Upland Areas Probably excellent. These perennial plants are virtually always grown as annuals, and with their fast maturity should fit well into many climatic niches with abbreviated growing seasons.

Beyond Africa

Garden eggs are already commercially grown in a few other places—notably Brazil, the Caribbean, and Southeast Asia. The Internet carries guidance on growing them in Britain.[15] We see no reason why this species cannot expand in global scope, although uncertainty fogs the exact extent of its adaptability to cooler climes.

USES

There are two food products from these plants, fruits and leaves.

Fruits Typically in Africa, the garden egg is chopped, cooked and mixed into a variety of vegetable, meat, or fish stews and sauces. Although bitter taste is a major characteristic, many African eggplants are sweet or bland, especially in the immature stages in which they are eaten. The unripe fruits are usually cooked in a sauce after being chopped, parboiled, ground, or otherwise prepared. Peeling is unnecessary because the skin becomes tender enough to be consumed along with the rest. They are among the few vegetables that reach full flavor only after being cooked *beyond* the crisp stage.

Leaves Africans eat the leaves of at least certain types of the Gilo Group eggplants. Although these leaves are high in solanine, which is toxic,

[15] According to one report, the berries of all species ripen throughout the British summer, with most plants bearing green unripe and colored ripe fruits simultaneously .

cooking apparently renders them harmless.

Ornamental Uses Not too many vegetables can take your breath away just with their looks. But African eggplants can. The fruits come in types that can be very ornamental, gleaming in more colors than the rainbow. The plants themselves are attractive small bushes that can be light or dark green, or purple, with tiny to very large leaves.[16]

NUTRITION

These fruits are far from nutritional powerhouses—they contain 92 percent water, after all. Nonetheless, they also contain small amounts of protein, vitamins, minerals, and starch. They are moderate sources of beta-carotene, B vitamins, and C. They also contain calcium, iron, potassium, and probably other minerals.

By the standards of the modern Western world, this veggie is a diet-doctor's dream: low in sodium, low in calories, high in dietary fiber, and a good source of potassium. It is used as a meat substitute not because it is high in protein, but because its spongy texture easily absorbs the other food's flavor while providing a mouthfeel vaguely suggestive of the presence of meat.

The seeds scattered through the fruit also contain vitamin C and carotene and other nutrients.

The leaves are excellent sources of vitamins A and B (particularly riboflavin), calcium, phosphorus, and iron. They contain about 5 percent of a protein containing significant amounts of methionine, one of the essential amino acids most difficult to find in plant-based foodstuffs.

HORTICULTURE

This crop is mostly grown on a small scale in compound gardens. It likes full sun, well-drained soil, or raised beds.

Propagation is by seed, which can be broadcast or drilled directly into well-prepared ground. Typically, however, the seeds are first sown in boxes or nursery beds. Germination takes about a week. After a month, when seedlings are 5-10 cm high, they are transplanted into the garden beds. The plants take at least a further month to establish themselves, after which they develop strongly.

For fruit production, plants of the Gilo Group are typically spaced 1 to 1.5 m apart. This spacing allows for the vigorous horizontal branching of these deciduous shrubs, which grow 1m tall unpruned.

Although less susceptible to disease than many vegetables, the crop is

[16] In this regard, it is notable that when the common purple eggplant first arrived in the United States it was grown for its beauty. That was in 1806 when Thomas Jefferson planted it at his home in Monticello. And the African ones are the most beautiful of all.

attacked by a fungal leaf spot and by several insect pests, including leaf beetle, moth larvae, bud borer, and sucking bugs. (The plants are normally grown during the rainy season, solely to avoid the pests that build up during dry weather.)

The plants branch profusely, a feature making weeding difficult. In time, however, this propensity itself helps by shading out most competitors.

HARVESTING AND HANDLING

The perfect eggplant is picked while still immature—about 70-90 days after sowing. At that point the skin is glossy and firm, the flesh white, and the seeds tender and fully edible. It is best to use a knife or pruning shears to cut the fruits from the plants. Harvesting continues over a period of 8-10 weeks. Yields vary, but in one test, three plants (grown on a small plot 1m x 4m) produced 10 kg of fruits.

The production of leaves usually involves different horticultural techniques. In this case, the plants are severely cut back to a height of not less than 5 cm after which a massive growth of young shoots occurs. Regular harvesting of the young shoots and debudding encourages the production of side shoots that extend the harvesting period. A total of five to eight weekly harvests are usually possible.

The post-harvest handling of the fruits has not been thoroughly evaluated, but the only unusual challenge noted is a rapid browning of the skin after harvesting. Growers currently minimize this by picking fruits gently and in the cool of the day, avoiding exposure to the sun, and—where possible—putting in cool storage for a few hours, but many tricks undoubtedly remain to be learned.

LIMITATIONS

The very thought of growing African eggplant is likely to raise hackles in some quarters. Its flowers betray its relationship to a notorious weed that adversely affects some of the world's main crops—the small, bell-shaped, purple bloom is utterly nightshade. Indeed, the whole plant looks like the black nightshade, *Solanum nigrum*.[17] For this reason, it will be difficult to promote it as crop plant in, for example, the United States, Canada, New Zealand, Britain, or Israel. Of course, the common eggplant is not problematic in those countries, but people bringing in its cousin will find the guilt-by-association with a more distantly related weed hard to overcome.

The Solanaceae (or Nightshade Family) is renowned for protecting its leaves with lethal compounds. The toxins occur to greater or lesser degree, depending on the species and the parts of the plant. Some solanaceous

[17] Several decades ago, the juice from squashed black-nightshade berries was estimated to damage more than 10 percent of the bean crop in Nebraska alone.

This is a resource that is easy to raise, relatively free of disease and pests, and capable of providing a steady supply of both food and income. The plants are notable for a capacity to yield a lot of food from a small space. It is also, as can be seen here, rich in genetic diversity. (G.J.H. Grubben)

species have perfectly edible parts but, despite all the evidence of their safety, people typically fear the worst. When the common eggplant was first introduced to Europe, botanists prophesied that consuming it would cause insanity.[18] Potato, tomato, and peppers—all of which are nightshade

[18] When the common eggplant turned up in England, John Gerard advised readers of his 1597 Herball to avoid it and "rather...to content themselves with the meate and sauce of our owne country than with fruit and sauce eaten with such perill; for doubtless these apples have a mischievous quality; the use thereof is utterly forsaken." In France, eggplant was rumored to provoke fever and induce epilepsy. One tome described it as having "fruit as large as pears, but with bad qualities."

relatives—were in their time claimed to be deadly too.[19] African garden eggs can expect the same.

A third misunderstanding likely to limit support for African eggplant has to do with the crop's public image in Africa, where it is seen as a low-status vegetable associated with poor people. As evidenced by poor-person's crops before it—potato, soybean, peanut, pea, oats, and barley, among them—this mindset can hold back a truly exceptional new food for decades or forever.

The garden eggs (like the common eggplant) must be harvested at just the moment when the fruits have developed full size and still remain firm to touch. If they are left to mature, the skin turns dull, the flesh spongy, and the seeds turn hard and dark. Prompt picking also increases fruit set and boosts overall yields.

NEXT STEPS

For all intents and purposes, African eggplants have received no production research. Most national agricultural research or extension systems allocate no personnel or resources to these vegetables, which they generally consider low-priority species. This needs to change. Agriculture schools and farming programs across Africa should initiate localized eggplant support and improvement projects.

In addition, public interest in the greater use of garden eggs needs to be kindled. Indeed, these veggies could quickly fit into development-support programs across the continent—programs dealing with such things as urban agriculture, soil protection, traditional foods, home gardens, sustainable development, women's welfare, and rural development.

There is also a need to foster optimal cultivation practices. This is not a call for delay and long-term research operations; instead, it is a suggestion to take whatever knowledge is already available and make the most of it. In this regard, indigenous knowledge on the plant types used in the various countries should be gathered. Socioeconomic surveys on the production and use of garden eggs in traditional settings across Africa are warranted as well.

Programs to provide bulk samples of quality seed might also be helpful in promoting the greater appreciation for a neglected crop that is under almost everyone's nose.

Organizational Support At present, the exchange of eggplant germplasm and related information occurs mostly via accident and personal contacts. In practice, only a small part of the potential knowledge and germplasm is available to agronomists, vegetable breeders, growers, and whatever seed organizations exist.

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[19] According to accounts, the daredevil Colonel Robert Gibbon Johnson stood on the steps of the courthouse of Salem, New Jersey, and publicly defied death in 1820 by eating a tomato. A crowd was on hand to enjoy the spectacle of this fool's suicide.

As backup support, it would be good to have some sort of functioning African-eggplant promotion and coordination undertaking. This need not be elaborate or even formal—funding in this case being less important than any kind of forward movement. But a fiscal means for sustaining interest and providing specific help and stimulation would be exceptionally supportive.

One thing to be done is to gather the natural diversity of eggplant across Africa. As noted, the types to be found are amazingly varied. A start on this has been made already, and seeds of several different types are housed in the vaults of international seedbanks. But local initiatives can still do much to gather the germplasm in the exceptionally diverse and dispersed habitats, not so much to conserve it but to get the best into wider use.

Another thing is to establish an eggplant database, into which research information could be incorporated, and subsequently disseminated to farmers, researchers, and interested amateur gardeners. Accurate and illustrated botanical descriptions of the local 'cultivars' used as vegetables could also be useful.

Food Technology In the advancement of this neglected resource, there are many things to capture the interest of food technologists. For one, African eggplant should be tested as a substitute in recipes developed to exquisite perfection for its famous Asia-born counterpart in countries such as Greece and Turkey.

For another, although no specific mention of toxicity has been reported, this species belongs to a genus some of whose many members have poisonous leaves and sometimes also unhealthy fruits. This is now the time to clarify once-and-for-all the African eggplant's potential for disaster.

For a third, the whole issue of post-harvest handling of the fruits deserves to be analyzed and formalized.

Horticultural Development The species can be considered an almost-blank agronomic slate, and almost any studies relating to its production—from seeding depth to thinning the fruits to increase their size—merit clarification. Horticultural investigations are especially needed to determine the field conditions that promote optimal growth and maximal harvests.

Genetic Development There are excellent chances for genetically enhancing African garden eggs for increased yield and other features through simple selection and/or plant breeding (perhaps including hybridization). There is a need to create (or identify) varieties better adapted to specific growing conditions. In addition, there is potential to create varieties with fruits of even more shapes, colors, and tastes.

Fuller use of genetic diversity can also raise public and industry's use of the crop. That, in turn, will lift its commercial value and profile.

In biotechnology exist many other possibilities. Breeders can likely take

advantage of the advances made in related solanaceous species. For instance, genetic maps of potato, tomato, peppers, and the common eggplant are available. Markers common to African garden eggs and those well-mapped Solanaceae should be identified. Such markers should allow the molecular tagging of agronomic traits and provide powerful tools for breeding whole new worlds of African eggplants.

Genes for Improving Other Crops Because of their genetic closeness to major global crops in the Solanaceae, African eggplants may also provide powerful tools to the breeders of such things as tomato, potato, and eggplant. They contain several traits potentially useful in improving those crops. These include resistance to:

- atrazine (a herbicide);
- tobacco mosaic virus;
- potato late blight;
- phomopsis fruit rot; and
- verticillium wilt.

Genes for these might possibly be isolated from Africa's garden eggs and genetically engineered into eggplant, potato, tomato, and peppers.

In addition, the species has been reported as showing molluscicidal activity, and may prove useful in controlling garden snails, slugs, or maybe even the water snails that harbor lifestages of the schistosomiasis parasite.[20]

Moreover, it has been claimed that this crop serves as an alternative host for a variety of pests, bacteria, and fungi that affect a number of commercial crops. African eggplants might therefore be used to lure away the pests.

As noted earlier, there are indications that African eggplant is resistant to soil-borne diseases caused by the very serious pathogens, *Fusarium oxysporum* and *Verticillium dahliae*. Perhaps it has a potential to be used as a way to avoid soil sickness.[21] Scientific exploration is well warranted.

New Locations Should the outside world try African eggplants? We think yes. The crop already grows in Brazil, and its potential for other tropical countries is high. It may even prove successful in Mediterranean nations. Those are also the ones that rely on eggplant, and they may find the extra drought-tolerance of the African version notably valuable.

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[20] We are somewhat skeptical of this possibility because in England slugs are said to be among the crop's worst enemies.

[21] T. Yoshihara, Y. Hagihara, T. Nagaoka, S. Chiba and S. Sakamura. 1988. Fungitoxic compounds from the roots of the eggplant stock. *Ann. Phytopath. Soc. Japan*. 54: 453-459. The biologically active compounds have been identified as several kinds of sesquiterpenes.

Exports and Marketing Within Europe and the United States, there is a strong tendency toward horticultural diversification, not only in the size, shape, color and taste of the well-known fruits and vegetables, but also vegetables that are new to the markets. Furthermore, some new eggplant species could be introduced to satisfy the consumers' continual demand for novelty products.

Taxonomic Clarification *Solanum* taxonomy has been clarified and resolved so often that outsiders have almost lost faith. African eggplants offer a world of possibilities for overcoming taxonomic difficulties in this important family because they lie somewhere among potato, tomato, peppers, and the common eggplant. DNA and other sophisticated evidence might clarify and resolve the uncertainties all over again.

SPECIES INFORMATION

Botanical Name *Solanum aethiopicum* L.

Synonyms *Solanum gilo* Raddi, *Solanum olivare* Paill. & Bois. *Solanum pierreanum* Pailleux & Bois.[22]

Family Solanaceae (Nightshade Family) section Oliganthes

Common Names

Arabic: begingan et gut a
English: mock tomato, scarlet eggplant, Ethiopian eggplant, African bitter pea-aubergine, wild pea-aubergine, wild African aubergine, tomato-fruited eggplant, Ethiopian nightshade,
French: tamate amere, aubergine amère, petite bringelle maronne (Africa)
Nigeria: asun (Shum group), ikan, igba (Gila group)
Sudan: guta, quta, begingan et gut a (Ar)
Swahili: ngilo
Uganda: nakati, nakasuga (Lug), abugarra (Yr/Tr), (n)jagi (Ach/Gis), enjagi, entura (Yr/Tr/Kig), etanga (Ank)
Chinese: Xiao gu qie, Xiao ku fan qie (Cantonese)

Description

In the vegetative stage, a plant of the Gilo Group looks like a common eggplant (i.e., *Solanum melongena*). It is a fairly woody deciduous annual, or occasionally perennial, herb up to 100-150 cm tall. It is not prickly. The

[22] Other possible synonyms are *Solanum integrifolium* Poiret, *Solanum integrifolium* Poiret var. *microcarpum*, *Solanum naumannii* Engl., *Solanum zuccagnianum* Dunal

mature leaves are smooth, apart from minute glandular hairs. Features distinguishing it from the other species are the small, white, star-shaped flowers. In addition, the calyces are never long and the inflorescence has a short (1 cm) rachis. The fruits are 3-6 cm in diameter, varying in shape from ellipsoid to almost round. They contain 2-6 locules and are normally firmly attached to thick fruit stalks that turn downwards. The flowers are pollinated by large bees.[23]

Distribution

Within Africa The plant occurs in virtually all of sub-Saharan Africa, but is less well known in (maybe absent from) South Africa and Madagascar.

Beyond Africa Centuries ago, the plant was taken to Brazil, probably with the slave trade. Brazilians call it "gilo," a slight corruption of the name used in East Africa, ngilo.

Horticultural Varieties

There are few named varieties, perhaps better called local landraces.

Environmental Requirements

The crop's ecological requirements are thought to be much like those of common eggplant, although *Solanum aethiopicum* is probably slightly hardier, and more tolerant of drought.

Rainfall 500-1200 mm or more. The plants thrive during the rainy seasons in the tropics.

Altitude Up to 1200 m.

Low Temperature Optimal temperatures for the growth of these plants lie between 20 and 30°C, and perhaps higher, but the species likely will grow well at temperatures down to 15° C. (The optimum germination temperature lies between 15 and 30°C, although temperatures fluctuating between these values are apparently required to break the seed dormancy.)

High Temperature The species seem to grow well within an upper temperature of 35° C.

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[23] Contributor Barbara Gemmill wrote, "Eggplant flowers have "poricidal" anthers, which means a bee must bite the anther and vibrate its wings at a certain frequency for the pollen to be released (a process called "buzz pollination"). Only certain, usually large-bodied bees like carpenter bees are able to do this; honeybees cannot buzz-pollinate."

Soil An easily grown plant, it succeeds in most soils. Nonetheless, it does best in soils of high fertility, especially those high in nitrogen and phosphorus. Sandy loam to friable clay soils with a pH range of 5.5 to 6.8 have been declared "particularly suitable." However, one report from Britain notes that "providing the soil is well drained, the actual soil type appeared almost irrelevant to good growth."

Photoperiod Believed to be day neutral.

Related Species

Gboma eggplant The present chapter has focused on the gilo eggplant, *Solanum aethiopicum*, but it might well have dealt with this gboma eggplant, *Solanum macrocarpon*. The two are similar in all but a few details of the flowers and leaf hairs. Virtually everything said in this chapter is true also for the gboma eggplant.

This is another species that might be more widely and more intensively cultivated than at present. It is perennial, glabrous, and shrubby. Originally from tropical and equatorial Africa, but widely introduced into Southeast Asia, this species produces a small fruit similar to the eggplant. The fruits may be eaten when very small, often raw, but in many places the plant is grown chiefly for its edible leaves.

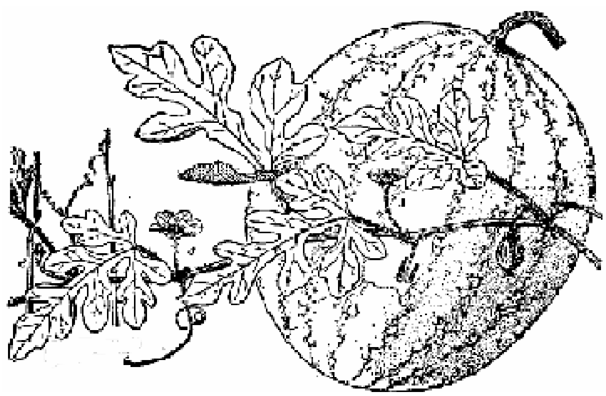
Truly lost "eggplants" In West Africa can be found *Solanum scabrum* L. and *S. americanum* Mill. The leaves of these two wayside plants, along with many other *Solanum* species, such as *S. nigrum* from the Americas, form the ubiquitous "African spinach", important (but potentially toxic) food resources that only recently have drawn the attention of scientists.

Close cousins There are, as noted, relatively distinct groups within the species *Solanum aethiopicum*.[24] Those with special potential are:

- *The Shum Group*. This has fairly small, subspherical fruits and small glabrous leaves. Only the leaf is used (the fruits being too bitter). It is distributed throughout Central Africa, as well as in western equatorial Africa, Nigeria, Benin, Togo, and Ghana.

[24] The species exists in different forms, which were in the past described as about 20 species. Recent studies have shown that all these plants are highly interfertile, and better treated as one species, having arisen by domestication from a single wild progenitor: *Solanum anguivi*. Four main groups of cultivars of *Solanum aethiopicum*, with different uses, are now recognized: the Shum, Kumba, Gilo and Aculeatum groups. The first three are native to Africa; the fourth grows in Europe, and has inedible fruits.

- *The Kumba Group*. This has much-lobed glabrous fruits that are pumpkin-shaped and only slightly bitter. When ripe, they are light green to red-orange—very ornamental and unusual looking with lots of bumps. Both leaves and fruits are eaten. The species is restricted to the sub-Sahelian region from Senegal to the top of Nigeria—a coverage reflecting that of the old Mali Empire.



8

EGUSI

The egusi plant looks so much like a watermelon plant that most botanists think it is one. The fruit looks so much like a small, round, watermelon that the two are also easily confused.[1] However on the inside the egusi fruit is neither red, nor luscious, nor sweet. Indeed, it is white and dry and bitter enough to be repulsive. This is one fruit not even monkeys bother with. But for all that egusi *is* a food crop…and far from a small one at that.

Egusi[2] is grown for its seeds, which resemble large, white, melon seeds. In West Africa, a region where soups are integral to life, they are a major soup ingredient and a common component of daily meals. Coarsely ground up, they thicken stews and contribute to widely enjoyed steamed dumplings. Some are soaked, fermented, boiled, and wrapped in leaves to form a favorite food seasoning.[3] They are also roasted and ground into a spread like peanut butter. Some are roasted together with peanuts and pepper and ground into an oily paste[4] that is used when eating kola nuts, eggplant, and fruits. Egusi-seed meal is compacted into patties that serve as a meat substitute. It is even said that the dry seeds placed on a hot skillet pop like popcorn and come out looking like puffed rice.

Beyond their use in processed form, egusi seeds are commonly parched and eaten individually as a snack. In his recollections of life in Ghana, one commentator notes: “Whenever a group of men were standing around talking, their hands were usually busy dehulling [shelling] egusi seeds.” And another recalling life in Cameroon notes: “On many an evening or hot afternoon in farming villages, women sitting with their families will be deftly and rapidly shelling the seeds ready for sale or home cooking.”

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[1] Watermelon is also an African native. For details, see companion volume on the fruits of Africa.

[2] In Ghana and a few other countries it is called “neri.” Egusi (some think the term derives from Yoruba; some from Hausa) has become the generic name for the seed across West Africa’s many linguistic boundaries.

[3] In Nigeria this is known as “ogiri-isi” and in Benin “avrouda.” It typically comes with or without dried shrimp.

[4] Called “ose-oji” in Nigeria.

Northern Namibia. This plant is easy to grow. Indeed, it survives on barren sites, not to mention some of the driest and most climatically challenged locations. Further, it blankets the soil and helps protect the land. Most of all, though, this vigorous annual suppresses weeds. After a month, fields planted with egusi are typically weed free. (Arne Larsen)

As we have said, this is no minor food. Almost all the big markets in Benin, Cameroon, Ghana, Nigeria, Togo, and the other nearby nations sell the seed. Egusi is in high demand in tropical markets, especially in the peri-urban and urban markets. Exactly how much is sold is unknown, but as far back as the 1960s Nigeria was annually producing 73,000 tons. Today the figure is likely much greater, and about a dozen other nations also grow egusi. The area under this crop is not insignificant, either. In Nigeria during the 1970-71 planting season more than 360,000 hectares were reportedly planted to it. In the 30 years since, egusi production has spread further.

Although outsiders might assume this melon seed to be merely a localized specialty, it actually has universally acceptable flavor and food-processing qualities. Indeed, it is already being introduced to other nations.

It is, for instance, available either whole or in flour form wherever African food is sold…notably in Europe and the United States. It is also peddled over the Internet, and apparently very successfully; search engines turn up scores of online egusi dealers.

Oil makes up the seed's largest nutritional component, averaging more than 50 percent...a figure so high that among major foods only peanut can match it.[5] In composition the oil is almost ideal. One recent analysis recorded its fatty-acid makeup as 63 percent linoleic and 16 percent oleic. And this highly polyunsaturated lipid is widely used. In northern Ghana one survey found that although shea[6] was the major cooking oil, egusi oil ranked next in importance.

Despite being a significant foodstuff even by global standards, egusi is hardly known to nutritionists outside a few West African nations. That is more than a pity; the seed could be an exceptional tool for nutritional intervention wherever protein-calorie malnutrition occurs. Although more than half its weight is edible oil, another 30 percent is protein. And that protein has high nutritional quality. The seed also contains important amounts of vitamins, especially thiamin and niacin. Additional dietary bonuses come from its levels of minerals.

This is a nutritional combination of unmistakable portent considering that the crop thrives where milk is largely unavailable (mainly because the presence of tsetse fly means an absence of cows). A high-energy, high-protein concentrate like this might ideally complement Africa's prevalent diets based on starch-rich grains (sorghum and maize, for instance) and roots (notably cassava). It doesn't take much of any food that is half oil and almost a third protein to provide the calories and amino acids that stressed, sick, and fast-growing bodies need each day. Egusi could thus be a vital tool against marasmus, kwashiorkor, and other debilitations.

This plant is not difficult to grow. Indeed, it grows so easily it could be called a farmer's friend. Many West Africans raise it and it normally yields very well for them. It is largely free of pests and diseases. It survives on impoverished sites and in forest clearings, as well as in some of the most climatically challenged locales. And wherever if grows the plant blankets the soil and helps protect the land. Most of all, though, this vigorous annual suppresses weeds. After 4 weeks of growth, fields with egusi in them are typically weed free.

Often the plant is grown alone. Sometimes it is grown in unused places around the fields, such as banks and bunds. But mostly it is interspersed among other crops, a combination that is especially appreciated because egusi takes care of the weeds. Normally, fields of crops such as sorghum,

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[5] The figure is based on the dehulled seed, the kernel, which is the edible portion. By comparison, peanut has roughly 48 percent oil and 25 percent protein. Soybean weighs in at about 18 percent oil and 38 percent protein.

[6] See Chapter 17.

WHAT IS EGUSI?

In this chapter egusi is presented primarily as the seed of one species, *Citrullus lanatus*, a type of watermelon. That species is indeed very popular, thanks to its productivity and food quality. But in reality, the situation is confused because the name egusi is applied generally to any of several similar looking seeds. All these seeds come from cucurbit species (family Cucurbitaceae) and all have high oil and protein contents. In some West African countries the main egusi crop may be *Cucumeropsis mannii* (*Cucumeropsis edulis*). Seed of the gourds *Lagenaria sicceraria* and *Telfairia occidentalis* are also consumed as egusi. All are cultivated on a large scale in West and Central Africa as they are easy to grow and their seeds are popular foods, and most of what we say here applies to them as well. Sometimes outside Africa, "egusi" can also refer to the bitter apple or vine of Sodom, C*itrullus colocynthis* (Linnaeus) Schrader; in turn, this scientific binomial is not to be confused with *Colocynthis citrullus* Linnaeus, which is a botanical synonym for *Citrullus lanatus*, the egusi treated here.

cassava, coffee, cotton, maize, or banana require two, three, or more weedings during the growing season. An intercrop of egusi cuts that to one.[7]

In spite of nutritional value and benefits to farmers and the land, this nutritious age-old resource is languishing. But this plant has so much to offer that it deserves concentrated local, regional, and international attention. A tasty seed that is not only rich in oil but rich in protein could be of exceptional value in most parts of Africa, especially where chronic malnutrition strains health and drains initiative. Indeed, egusi is already to be found in many of the nations on which dietary deficiencies hang heaviest, but is not being fully harnessed for humanitarian good.

Additional justification for the notion of a major egusi initiative comes from North American research. For over a decade U.S. Department of Agriculture scientists have studied the seed's nutritional and functional properties. The research leader, John Cherry, is convinced the crop has a future. "Egusi-seed flour contains excellent quantities of the major nutrients, oil, and proteins," he reports. "The essential amino acids in the proteins of

[7] To the farmer, this is a boon. Consider the conclusion of an article by the International Institute of Tropical Agriculture in Nigeria: "Studies at IITA and elsewhere show that crops such as maize and cassava interplanted with egusi need to be weeded only once (within 2-3 weeks) after planting if the melon is grown at densities of 20,000 plants per hectare….Ground cover by egusi suppresses weeds until the melon is harvested, by which time the crops have developed a canopy cover of their own." At that point, the main crop shields the ground and suppresses the weeds without egusi's help.

the flour make it a good vegetable protein."

A separate USDA research group has concluded that egusi could find a place in the food industry. Its promise is for thickening, stabilizing, and fortifying processed products. The group's analyses were mostly done on defatted, low-hull flour—the form most appropriate for processed foods. It proved to have high water and oil holding capacities; it formed thick and stable emulsions.[8]

Despite its promise for the food industry, it is the small-scale, subsistence use that most concerns us here. In this regard, foods produced from locally grown egusi seed could improve diets in many an African country whose population currently suffers inadequate diet. Egusi seed compares with the best-known high-protein/high-fat food plants, and it is indigenous. Noteworthy is the fact that the seeds can be stored for long periods. This is one oilseed that can supply quality food year-round.

Given attention, the plant is likely not only to improve nutrition but also farmers' income. A women's group of central Benin (Bante) cultivating 10 hectares of egusi earned more than they would have from cotton, the region's main cash crop.

Indeed, when grown well, egusi boosts soil quality too. And its benefits are likely to be felt not only in West Africa but also in eastern and southern Africa, and perhaps elsewhere.

Women would be special beneficiaries. Although in some places women grow egusi, in the main they are they the ones who harvest and process the crop. Generally speaking, they receive relatively high cash income for their work. Indeed, the "egusi wage" is regarded as the standard for women's agricultural payment for all tasks, and the women defend it with determination because it sets the standard of their lives. Any improvement in egusi's profitability will directly help millions of women of all ages and all rural jobs.

PROSPECTS

Although it now gets no particular support from national or international agronomic research organizations, egusi could be made into a nutritious and tasty food for much of the continent, if not the world. At least within West Africa, getting people to consume more and farmers to grow more should be easy, so long as seeds for planting are available and the harvest continues attracting a fair price.

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[8] The authors wrote: "Protein isolates that differ in gel electrophoretic patterns and amino acid content can be prepared from the flour in one- or two-step water and sodium hydroxide extractions," wrote the researchers. "The water and oil holding capacities of the flour are 0.7 and 2.6 ml/g, respectively. Thick (mayonnaise-type) emulsions form in the alkaline pH range and a stable foam forms at pH 5.0."

Within Africa

Egusi is notable for tolerating an extreme range of conditions, from damp to dry.

Humid areas More than a dryland plant, egusi (or its close relatives[9]) grows in equable sites. It is an especially promising food for the regions of lower West Africa, where cows cannot thrive and milk is in consequence a rarity.

Dry Areas As noted, the plant resists drought and has long supported people dwelling in West Africa's dry regions. It is not so drought resistant as to thrive near the true desert, but it is well adapted to the semiarid zone (incorporating, for instance, the Guinea savanna, Sudan savanna, and the sub-Sahelian region) that lies halfway between the Sahara and the sea.

Upland Areas Wherever watermelons grow, egusi should grow too. Thus, many tropical highlands as well as warm temperate locations are candidates for at least trialing the crop.

Beyond Africa

Egusi seeds are potentially a source of quality protein for many countries. However, beyond Africa they may not catch on in a big way. For one thing, consumers may not immediately take to eating a melon seed. For another, it is hard to produce this sprawling plant on a scale to compete with other mass-produced oilseeds. Egusi is therefore most likely to stay a specialty crop for sale in African food markets. However, roasted pumpkin seeds have become a fairly widespread snack in the United States; egusi could perhaps become a counterpart. Not only is it tasty and nutritious, it likely would sell at a premium.

USES

Even ignoring that some egusi-seed "suppliers" are gourds and melons with their own individual uses, this is a multiple-purpose food.

Seeds The seeds are shelled (dehulled) and the kernel is ground into a flour. As already mentioned, that flour enriches and thickens soups as well as other foods. The whole seeds are dry-roasted and consumed as a snack. Pounded roasted seed produces a paste. Known as ose-oji in Nigeria, this peanut-butter-counterpart may be spread on bread, mixed with other foods, or dropped into soups and stews.

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[9] The seeds seen in certain marketplaces certainly look like egusi but may well come from related species (see below).

London grocery store. Egusi is increasingly exported to Europe. In Brussels it is sold under the Congolese name, mbika. In Paris, retailers use the (North African, Asian and Cameroonian) name of courge. In London and Madrid, the seeds are sold under the commercial name of egusi. (Honoré Tabuna)

Oil In West Africa egusi oil is sometimes extracted, but so far only on a small scale. It is used in cooking and seems suitable as salad oil. The seed has occasionally been exported to Europe for processing into vegetable oil.

De-fatted Meal The solid remaining after the oil has been squeezed out contains 60 percent protein. This remarkable defatted solid can be ground into flour with myriad dietary uses. It is mainly used as a meat substitute.

Leaves It is reputed that the young, tender leaves may be cooked and eaten as a potherb.

NUTRITION

Despite its widespread importance as food, little nutritional detail is readily available to an international readership. In general, however, the kernel contains about 50 percent oil, 30 percent protein, 10 percent carbohydrate, 4 percent ash, and 3 percent fiber.

The protein content compares favorably with that in the most renowned legume seeds.[10] The exceptional level of essential amino acids makes the

[10] Egusi seed's protein content (average total nitrogen 5.75 percent) is higher than in

protein composition special. Egusi is an excellent source of arginine, methionine, and tryptophan. The biological indices of its protein quality have been described as: “lower than soybean but comparable to or higher than most oilseeds.” Nutritionally, the limiting amino acids are lysine and threonine.

Several micronutrients also contribute to human nutrition. Vitamins occurring in notable quantities include B1, B2, and niacin. In one analysis the highest mineral component was phosphorus, followed by potassium, magnesium, manganese, sulfur, calcium, iron, and zinc.

Soluble sugars and starch make up the bulk of the carbohydrates.

Only a few nutritional trials have been conducted. In general, however, significant growth improvement was reported when egusi flour supplemented traditional West African diets. The biological value, net protein utilization, and protein-efficiency-ratio proved comparable to or higher than those of standard oilseeds. The results suggest that egusi seeds have good potential for fortifying both traditional and modern food formulations.

HORTICULTURE

The crop is usually handled like watermelon or pumpkin, species to which it is not only related but similar in plant type and agronomic need.

Propagation is exclusively by seed. Although the exact planting method depends on site and situation, most is sown during the major rainy season, typically after the first few heavy showers. Generally, two or three seeds are placed in holes about 2 cm deep. Where conditions are conducive to good growth the holes are normally spaced about 1 m apart and two plants are allowed to grow per hole. A pre-planting application of complete fertilizer followed by dressings of nitrogenous fertilizer at intervals to maintain a regular growth rate has been recommended.

This is how egusi is produced in the Transition Zone located between the dry savannas and the humid coastal area. There, the crop is grown in dense, pure stands and it achieves its best productivity. There, too, the soil tends to be fairly high in organic matter and fertility. Also, the rainfall is high (1,400 mm) and well distributed throughout half the year (April to October).

In the more challenging zone immediately to the north (the Guinea and Sudan savannas, for instance), egusi is more often grown as a mixed crop, especially on ridges between sorghum. The soils here are poor in both organic matter and fertility; the rainfall low (800 mm) and brief. As a result, wider spacing (about 3 m between plants) is necessary. Understandably, then, production-per-hectare is much reduced.

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peanut and cowpea and slightly less than in soybean (6.65 percent). One advantage over soybean is that egusi seeds need no processing…there are no antinutritional ingredients to remove.

Whatever the overall conditions, most seeds germinate and within a week seedlings are emerging. Three weeks later, the vines nearly cover the ground and flowering starts. Often the fruits are ready to harvest 120-150 days (4-5 months) after sowing. However, in some locations they take 180-200 days to mature. The vines then wither and die.

As noted earlier, neither pests nor diseases much affect the growing plant. Variegated locusts have been reported to eat egusi seedlings (and everything else of course).

HARVESTING AND HANDLING

Once the fruits stop enlarging they can be harvested. The timing, however, is not critical…this is one crop in which there is no particular urgency to bring in the mature fruits. Within reason, they can remain in the field without serious loss.

In better-watered areas with reasonable soil the harvest averages five fruits per plant. In drier and more barren locations the yield averages two fruits per plant. Normally a fruit weighs between 0.8 and 1.5 kg, but those grown in the more challenging climates tend to be smaller.

The fruits keep well, and can be stored several months without decaying.

To remove the seeds West Africans employ several age-old methods:

- They break open the fruits with a hard stick and lay the pieces on the soil pulp-side down. After several days the pulp has decayed, freeing the seeds.
- They bury the fruits whole, and leave them to decompose a month or so underground.
- They crack the shells, heap the fruits up, and cover the pile to promote decomposition.

Following any of these procedures, the seeds are easily separated by hand or by a stream of water. They are then washed to remove any remaining pulp fragments and allowed to dry in the sun. The dried seeds are best stored in sealed containers. Certain beetles can ruin the whole harvest.[11] But given care the seeds can be stored almost indefinitely.

Before use as food the seeds must be shelled. At present, this is mostly done by hand.

LIMITATIONS

The plant often seems quite susceptible to root-knot nematodes as well as to waterlogged soil.

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[11] These notably include the red flour beetle (*Tribolium castaneum*) and the cigarette beetle (*Lasioderma serricone*).

This sprawling species is poorly adapted for mechanized operations. It seems unlikely, therefore, that it could compete on the world stage for the industrial-scale production of cooking oil or protein concentrate.

Despite having fed generations of Africans and despite its promise for feeding future generations, egusi has had very little development support. There is no standard method for measuring its yield. Its biology is virtually unknown. Its nutritive value is based on only a few samples that may or may not have been nutritionally representative. Even its scientific name and genetic relationship to several related plants is not without doubt.

NEXT STEPS

This crop has such high prospects it deserves intense and far-ranging research. And it seems quite amenable to rapid progress. An annual, it gives results quickly. It is relatively easy to manipulate and propagate for the purposes of crop improvement. Seed is available. And there are no major technical barriers to be overcome before advances can be achieved. Indeed, it should be able to ride piggyback on a wealth of research already available from its relatives—watermelon, melon, squash, and pumpkin—thereby saving much time and money.

Publicity This is not a resource that needs much introduction, at least in West Africa. Nonetheless, the knowledge about egusi and its many uses should be brought together and made available for the benefit of all. One project could be the production of a Farmer's Handbook on the best methods for planting and managing the crop. Another might be a compilation of the greatest recipes from the countries where egusi grows. Cooking contests and other challenges would be both interesting and beneficial to the public awareness of the crop's importance.

Rural Development Taken all round, egusi offers one of the best interventions for raising farm performance and nutritional performance in West Africa (and perhaps many other parts of the continent as well). Although it is not a legume, the crop should be at least tested in programs that use legumes. It provides high-protein and high-oil foods like soybean and peanut as well as ground covering capacity like mucuna or lablab.

Malnutrition Could egusi be used as baby food? An NGO in Ghana reports that blending 200 ml of water with 240 ml of dehulled seeds, and seasoning the result with a little honey and salt produces a mixture resembling mother's milk. This smooth, milky, liquid might prove useful as an infant-food supplement where neither mothers nor cattle can provide adequate milk, they say. Perhaps this could open the door to the long-sought homemade weaning food containing both the high energy and the quality protein needed to combat protein-calorie malnutrition in the very young.

That is not too hard to imagine. Every home in every village has a stone mill or small mortar and pestle. Using such simple equipment, the seeds are easily crushed into a peanut-butter consistency.[12]

Studies conducted by the Nutrition Centre at Bawku, in the Upper Region of Ghana, on the use of egusi as a source of protein and fat in the diet of children who show the effects of marasmus (lack of calories) and kwashiorkor (lack of protein) has proved to be satisfactory. In Benin, the defatted egusi flour, known as *fagous*, is used to make cake and it is also added to baby food.

Food Technology Egusi offers many opportunities for the world's food technologists to help reduce African hunger. For one thing, it could become a protein source in many processed foods as well as a supplement to cereal- and root-based staples. Such extended use will depend on the knowledge of its chemical properties, nutritional properties, and functional properties, such as those relating to thickening, stabilizing, and fortifying processed products. All of these await further elucidation.

In addition, the seed-extraction methods need updating. To produce egusi on any scale, you cannot rely on rotting away the pulp of billions of fruits. One approach would be to find uses for the flesh that is now wasted. Perhaps there are animals that will eat the intensely bitter material, but a more promising line of research would be to investigate the bitter compounds themselves. Even now, there's a demand for compounds for "bittering" consumer products and thereby deterring children from accidental poisonings. A natural product like this could perhaps have a marketplace advantage big enough to overcome the limitations of distance and doubt. Concentrated egusi-fruit-extract could even prove more profitable in international trade than egusi seed.

Another pressing need is mechanical shelling. Again, the crop cannot expand dramatically if all the seed must be shelled by hand. Clearly, people cannot deal with billions of seeds using their fingers. This operation is probably not too difficult to mechanize, given that pumpkin seeds are already treated this way on a large scale.[13]

Nutritional Research Egusi seed comes in various types, and there is a crying need for critical studies of the variation in lipid and amino acid components between them. The parallel relation between the species' genetic diversity and protein quality also needs to be better understood.

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[12] He also reports: "It does not form gas and the school children who have tasted it have not complained of any problems."

[13] John Cherry reports that a Bauer Mill with special teeth crack the shell and spit out the kernel with about 90 percent efficiency. There is, he says, no change in the color or texture of the resulting egusi flour.

Horticultural Development Like vegetables highlighted in other chapters, egusi presents agronomists, plant pathologists, crop breeders, and more with the chance to confront a new crop, to apply first principles, and to develop a baseline of technical knowledge that presently does not exist. Research challenges will be exposed on every side, however, a few of the things clearly needing investigation include:

- *Floral biology*. Though considered taxonomically just another watermelon, there are questions whether the plant is strictly monoecious, or perhaps occasionally dioecious, or mixtures of both? What are the most effective routes to pollination?
- *Germplasm*. The species' biodiversity needs to be gathered, conserved, and compared.
- *Varietal selections*. Elite types need development. Extra-large seeded types are one good target.
- *Agronomic details*. The optimal and minimal agronomic requirements should be better understood.
- *Yield*. There is a crying need for critical studies of how to achieve the greatest productivity. This may involve increasing the number of fruits per plant, the number of seeds per fruit, and/or speeding up the maturity time.
- *Edaphic effects*. Tests of the plant's ability to restore fertility and rehabilitate soil need to be run.
- *Crop limits*. The crop's limits also deserve testing. Is the egusi plant productive at high elevation? Under high rainfall? How about cool conditions? Scorching ones? What are its susceptibilities to disease and insects? Are there differences among individuals in such adaptabilities?
- *Acid soils*. This is one special limit deserving attention. Given its closeness to watermelon (which tolerates acidity as extreme as pH 5), egusi should be excellent for areas suffering from the burden of laterite, the red, mostly barren, acid soil that dominates many tropical regions.

Extend Egusi Beyond West Africa This would be a good time to test this crop in research studies across Central Africa, East Africa, the Horn of Africa, and southern Africa. *Citrullus lanatus* and *Lagenaria* species are well known in West, Central, East and Southern Africa and even in North Africa, but their usage varies from region to region. Some authors indicated that *Citrullus lanatus* originated from more than just the Kalahari Desert and surrounding areas. They include the southern Sahelian zones and neighboring savannas and arid areas.

Trials Beyond Africa Most nations now produce cucurbits—notably, watermelon, pumpkin, squash, and melon. The egusi plant is likely to grow well for them, too. People in the former Soviet Union commonly snack on pumpkin, sunflower, and similar seeds. Could egusi become a Russian or

Ukrainian crop? Maybe. The giant size of the seeds would be a good incentive. In addition, the plant might thrive in the Central Asian republics, whose aridity makes many crops difficult to grow.

It is worth getting egusi samples, using proper protocols, into the research programs on those related crops all over the world. Those specialists with lifetimes of experience with related cucurbits are likely to possess deep insights that can boost egusi and help Africa's food production right away.

Special Research Challenges A number of technological developments could help. These include:

- *Mechanical processing*. Post harvest handling constitutes a serious constraint for the production of egusi. Currently, a lot of labor and water are required to process the seeds. In addition, continual sunshine and clean drying areas are vital, because if the seed starts germinating its value plummets. Developing appropriate technologies or tools will do more than almost anything to boost this crop.
- *Dehulling*. In particular, a machine that facilitates the laborious extraction of egusi kernels will increase production almost beyond measure.
- *Hull-less types*. A diligent search may turn up "naked" egusi seeds (counterparts to those found in pumpkin). This would mean that people would not have to shell the seeds, which would save countless days of drudgery.[14]
- *Fuel*. Research should be undertaken to explore the possibility of sun-drying egusi roots and burning them. The roots are very large and, like those of other cucurbits, they dry to form a hard, wood-like material that makes good fuel for cooking stoves. In the semiarid zones, where egusi grows, sun is plentiful but fuel is difficult or impossible to obtain. Egusi-root could perhaps become a major fuel for the Sahel, which has been largely denuded by wood-gatherers.[15]

Taxonomic Clarification Is egusi really an aberrant watermelon? Perhaps this is a case where conventional taxonomy is inadequate for determining differences in the DNA. The flower structure may resemble a watermelon's and they can be interbred (though we heard no reports of "cross-contamination" being a problem in the field), but the two plant types are obviously not genetically identical.[16] Their other parts look quite distinct,

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[14] However, hull-less seeds might not survive the current method of extraction by rotting the fruits and would require a different mode of seed extraction from the traditional one.
[15] Information on cucurbit-root fuel from Gene Schultz.
[16] Through crossing trials, USDA researchers have found the characteristic fleshy pericarp of egusi seed may be controlled by mutation in a single recessive gene (which they term *eg*) in "normal" watermelons (Gusmini, G., T.C. Wehner, and R.L. Jarret.

and the two seem to come from different areas of Africa.[17] Modern technologies, such as DNA fingerprinting and cross-pollination trials under rigorous laboratory conditions, are needed to clarify whether egusi is an inedible watermelon or a distinct species.

As has been mentioned, the egusi seed seen in the markets actually comes from a variety of species, depending on the location and season. So, follow-up may actually expose a cluster of climbing, crawling, trailing, and creeping herbaceous plants with both individual and common promise—all of them masquerading under the name egusi.

SPECIES INFORMATION

Botanical Name *Citrullus lanatus* (Thunb.) Matsum. & Nakai var. *lanatus*

Synonyms The disagreement on egusi nomenclature is such that the botanical name is variously given as:

- *Citrullus vulgaris* Schrader (also watermelon)
- *Citrullus vulgaris* Eckl. and Zeyh. (also watermelon)
- *Citrullus lanatus* Thunb. (also watermelon)
- *Citrullus lanatus* (Thunb.) Mansf. (also watermelon?)
- *Colocynthis citrullus* (L.) Kuntze.
- *Colocynthis citrullus* Linnaeus

Family Cucurbitaceae, Gourd Family

Common Names

English: edible-seed melon, white-seeded melon
French: ononde, graines d'quonde, "sesame"
Fon: Goussi
Fulani: denne nai
Ghana: neri, niri
Nigeria: egusi, guna shanu (Hausa); denne nai (Fulani); ibara, bara, ito (Yoruba)
Spanish: calabaza pamué
Sudan: surat

2004. Inheritance of Egusi Seed Type in Watermelon. *Journal of Heredity* 95(3):268-270). Although "egusi" consists of a suite of other differences (such as dry, bitter flesh), and regardless whether one species or two, this discovery could open a door where the world of research understanding about watermelon could be confidently applied to egusi, and could also lead to new types of melons and seeds throughout the curcurbits.

[17] Both egusi and the watermelon are of African origin, but watermelon is native to the deserts of southern Africa and (given its present distribution) egusi seems to have arisen in West Africa.

Description

The egusi plant is a vine with a non-climbing creeping habit. Its leaves are deeply lobed and blue-gray in color. The pinnately dissected leaves are alternately arranged. They are glabrous or slightly scabrid, denticulate and about 24 cm long. The flowers are monoecious, solitary in axils yellow and measure 13-20 cm in diameter. The yellow-green fruits are about the size of a melon, reaching about 18 cm in length. Their skin is often shiny; the flesh white.[18]

The seeds are numerous, white, smooth, flattened, and narrow. Most are larger than watermelon seeds, but they vary in size and thickness. Basically, they come in three separate forms: small, medium, and large. They also vary in the texture of the seed coat, which may be thin, thick, or encrusted in bumps. And the thickness of the edges varies from flat to molded. About half the weight of the seed is in the hull.

Distribution

Within Africa The exact extent of egusi cultivation within tropical West Africa has not been determined. Likely, it stretches from Senegal to Sudan and perhaps as far south as Congo. Major egusi-growing nations include: Mali, Burkina Faso, Togo, Ghana, Côte d'Ivoire, Benin, Nigeria, and Cameroon.

Beyond Africa The crop exists outside Africa, but its uses vary and are little-documented.

Horticultural Varieties

Several varieties of egusi exist in Ghana, Benin and Nigeria. They vary in color or size of the fruit and the seed.

Environmental Requirements

So little has been reported about egusi that we here rely largely on the cultivation conditions reported for watermelon. (See Horticulture)

Rainfall Although drought-tolerant, the plant requires a steady supply of water for best fruit production. It needs only a small amount of rainfall (250-500 mm) for survival, since their deep root system efficiently exploits available soil moisture. Excessive rainfall and relative humidity reduce flowering, and encourage development of leaf diseases. Waterlogging kills the plant.

[18] For a full treatment of melon, see companion volume on the lost fruits of Africa.

Altitude Watermelons grow well up to 1,000 m in the subtropics, and may reach 1,500 m above sea level at tropical latitudes. Egusi probably acts similarly.

Low Temperature Watermelon requires a relatively long, hot, growing season (usually about 4 months of frost-free weather). For the seeds to germinate, the soil temperature at 5 cm depth must be at least 15°C. For growing watermelon the optimum temperature range is 23-27°C. Growth stops below about 18°C and the plant is very susceptible to frost. This limits production in regions with cool summers.

High Temperature Excessively high temperatures (over 30°C) during blooming may be harmful, reducing fertilization of the flowers. But such heat does not kill the plant. The wild melons in the southern African deserts grow where the temperature is often 36°C or more. Plants will tolerate even higher temperatures for short periods of time.

Soil Not unexpectedly, egusi yields are best on fertile humus-rich loose soil. It also grows successfully on soil of low fertility. Soil depth should be at least 10 cm. Watermelon tolerates not only acidity, but also alkalinity (up to pH 8.0); the optimum pH range, however, is 5.5-7.0.

Related Species

Egusi-ito[19] is a crop so similar to egusi that much of what has been said above can be applied to it as well. The plant is even less well known, it grows in wetter, more humid locations, and is a climber that is often grown up over the roofs of village houses. It is also often cultivated close to small trees and shrubs, fences, or similar support.

This white-seeded melon is grown mostly in Western Nigeria and Cameroon as an oilseed crop. Its oil is considered superior to that of peanut, and it sells for higher prices in the market. It is also a source of protein. It has been described as a species of immense potential as a new crop for the tropics and deserving of further investigation.

Botanically speaking, egusi-ito is a monoecious, partially drought-resistant curcurbit. The fruit may be up to 30 cm long and 10 cm in diameter. It contains numerous quite large seeds each of which may be up to 2 cm long. They are used like the seeds of egusi. In some parts of eastern Nigeria, the leaves are wrapped around fresh cornmeal and winged termites, cooked, and then eaten as a delicacy, mostly by women and children.

This plant is more promising than egusi at low elevations in moderately high rainfall areas.

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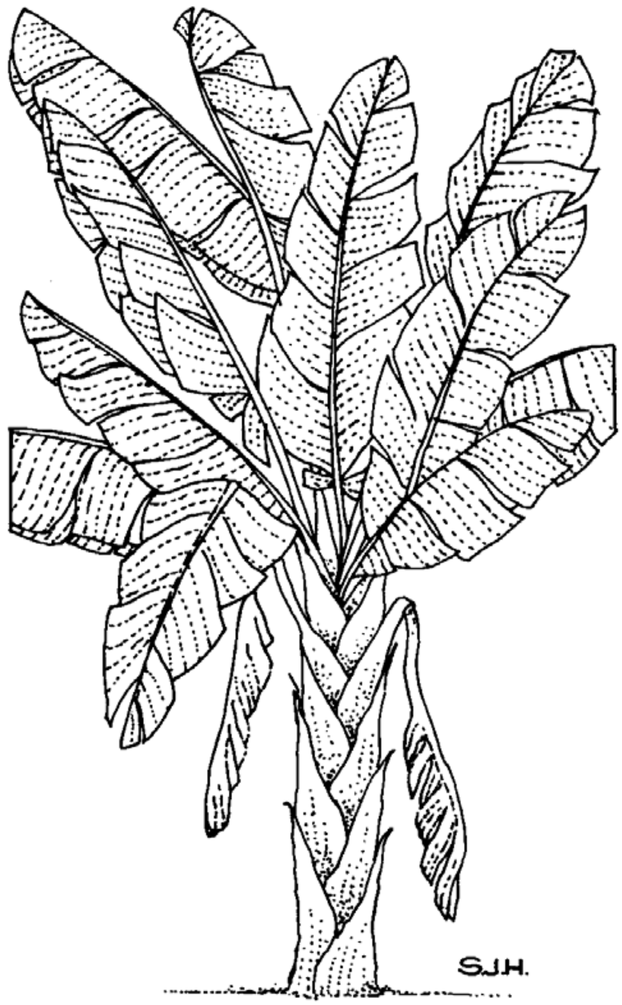
[19] *Cucumeropsis mannii* or *Cucumeropsis edulis.*

More Relatives

As noted, the "egusi seeds" in the markets may in fact derive from several species. The Gourd Family, to which egusi belongs, is represented in Nigeria by 21 genera and 41 species. Most are wild but a number are cultivated. Little-investigated relatives of economic importance include *Coccinia barteri* and several species of *Cucumis*, *Zehneria*, and *Momordica*.



Ensete ventricosum

9

ENSET

When drought struck Ethiopia in 1984 and 1985 a horrific tragedy unfolded as the food crops millions depended upon slowly succumbed. The horror was made all the more memorable because it unfolded before the eyes of the world, as television beamed the scene into households from Germany to Japan to Australia. Few viewers had ever witnessed in real time the specter of walking skeletons, children with bellies swollen as if pregnant, babies dying at their mother's breast. The images shocked the common conscience. They still do. "The world has seen a lot of suffering," said U.S. congressman Tony P. Hall, "but we still judge hunger against the depths of Ethiopia's hell."

Among the millions of sufferers were southwestern Ethiopia's Sombo people, who relied on cereals for their very existence. In the mid-1980s their fields of tef, sorghum, and maize produced little or nothing. Faced with empty shelves and empty stomachs, the Sombo decamped en masse. From their villages in Ilubabor Province they headed eastward, some trudging as far as 500 km to Woliso, a town hardly 100 km short of Addis Ababa itself. On this long and painful trek many died, but in the green highlands the survivors discovered a wholly new type of food resource, a vegetable taller than a house. During their enforced exile in that salubrious region so close to the great capital, they taught themselves to cultivate this huge herb. Returning to Sombo, they carried planting materials home, and the alien food grew to be part of their everyday diet. Already that has paid off. In 1992, a year of constant downpours, most of the coffee crop and up to 90 percent of the cereal crop succumbed to disease. This time, though, there was no famine and no trek in search of succor…the Sombos lived off their gigantic vegetable. Then, in the year 2000 drought again afflicted Ethiopia. By now the new food was well and truly grounded in the Sombo soil and culture. Once more, the suffering caused by empty shelves and long marches never arose.[1]

[1] This story and much of this chapter's detail come from *The Tree Against Hunger.*, posted at www.aaas.org/international/africa/enset. We are grateful for the authors providing so much information, much of it effortlessly via the worldwide web—a clear example of its broadcasting power; perhaps no other lost African crop has so quickly

This is far from being an isolated story. Although almost no outsiders have ever heard of it, this tree-like herb, perhaps the biggest of all vegetables, underpins much of the food supply in Ethiopia's highlands. Production is concentrated mainly in the areas south and west of the capital, but farmers in the central and northern stretches grow it too (mainly as an "ornamental crop" and to use the leaves for various purposes, but even here the plants serve as a living food depot).[2] In terms of production this is hardly a small crop; all in all, an estimated 10 million people consume it. The harvest probably amounts to 2 million tons a year, a quantity surpassing that of radish, parsnip, horseradish, and other better known and much better supported crops.

This species, known as enset [en-SET], is unlike any other food plant. Sure, it looks like a banana—thick-stemmed, erect, and towering over the land—but its fruits are all but inedible. In this case, the food is formed inside the stem. The largest specimens have a trunk a meter in diameter and 10 meters tall, and its uppermost portion, which can be three meters long, is filled with starchy pith. A second major food is found underground. This so-called corm may itself be almost a meter long and almost a meter in diameter, and it is packed with starch like some giant potato.

An individual plant producing food by the cubic meter is something of a marvel. This long-lived species represents a standing food supply, available for daily use or for the rare times when all other eatables fall short. But enset's importance extends far beyond food. Every part is useful for something. Southern-highlands farmers declare that, "enset is our food, our clothes, our beds, our houses, our cattle feed, and our plates." In other words, this is a crop of life; like coconut it provides a basis for subsistence culture…a fundamental resource for those whom even buying bare necessities is more a dream that a prospect.

Although only a glance is needed to see enset's importance for poor-people's food security, deeper investigation is needed to plumb its true value. Interviews with farmers suggest that Ethiopian peoples who depend on the plant have NEVER suffered famine.[3] According to eyewitness reports, only the edges of the older leaves and the sheath surrounding the inner leaves were affected during the 1980s drought years, and once the rains returned the plants resumed growing as if nothing untoward had occurred.

In a sense, it seems surprising enset isn't more widely known. The rural locations that rely on it are some of the most densely populated in Ethiopia,

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enjoyed such exemplar service in this emerging global medium.

[2] This northern arm of enset cultivation extends to Lake Tana, the Simien Mountains, and even Adigrat near the Eritrean border.

[3] Different ethnic groups use enset in different ways, but the main ones using it for food are the Gurage, Sidama, Gamo, Hadiya, and Wolayta.

Gurage Zone, southern Ethiopia. The plant is perhaps the biggest vegetable of all and looks like a banana “tree.” The food, however, comes mainly from the lower trunk, filled with starchy pith, which on the largest specimens can be a meter in diameter and three meters tall. A second food comes from underground, where a corm may be almost a meter long and a meter in diameter, packed with starch like some giant potato. Any plant producing food by the cubic meter is surely something to put to use in a hungry continent, but so far enset is barely known to science, let alone to Ethiopia’s neighbors. (Jürgen Bierwirth)

if not the world. What seem from a distance like fields for food production can be as crowded as a suburb in a city, commonly containing 200 to more than 400 persons per square kilometer. In fact, more families are squeezing in daily, and as the farms shrink to accommodate them, more and more enset is being grown. Any species that allows this sort of concertina contraction of the farmland would seem like a godsend for a crowded world. Indeed, this giant vegetable produces such huge amounts of food that a single plant supplies a family of five or six for a month. Although perhaps said with exaggeration, a family of five supposedly can feed itself forever from an enset field less than 10 m by 10 m.

You might think that such productivity would demand meticulous care of the land. But, surprisingly, enset farmers do little to maintain or improve their plots, other than add manure. Although traditionally they incorporated exceptional quantities of animal waste, it is still fair to say that the plant provides a long-term sustainable food supply with minimal inputs—an ability one writer considers “probably the most noteworthy characteristic of the enset plant.”

Also you might think that withholding inputs would hurt the land, which was far from fruitful in the first place. But that seems not to be the case either. Areas under enset actually appear to be in better shape than those around them…more fertility, more capacity to hold water, more organic matter, more tilth. Enset’s perennial leaf canopy as well as its abundant production of long-lived leaf litter reduces soil erosion and retards the vaporization of organic matter under the triple goads of tropical heat, tropical humidity, and tropical microbial action. It is said that many enset fields have been in continuous production for decades, if not centuries, and yet remain productive, stable, reliable.

As to enset foods, they are not the most nutritious—not by a long shot. For all that, though, they are not meritless. Traditionally considered fit only for impoverished farmers, they are now attracting the interest of the better off. Throughout Ethiopia the historical perception of enset as mere “peasant fare” is breaking down. Fine diners who formerly wouldn’t be seen over a plate of enset enjera[4] now demand it. And a fermented enset extract called kocho has become extremely popular in Addis Ababa, even in upscale restaurants.

Although this plant comes with many telling positives, it comes with telling negatives too. For one thing, enset produces food slowly; after planting, the really large quantities of food in the upper part of the plant can take 7 years to develop fully. For another, neither the stem’s starchy pith nor the corm’s potato-like pulp is well balanced, nutritionally speaking. For a

[4] Enjera is Ethiopia’s staple, a spongy pancake-like bread wholly unlike anything else in the world. The dough, which like sour-dough is fermented before cooking, normally comes from cereal grains, especially from the tiny seeds of Ethiopia’s own tef (*Eragrostis tef*). For details, see tef chapter in *Lost Crops of Africa. Volume 1: Grains*.

third, the planting materials are difficult to produce. Fourth, this clonal crop is quite vulnerable to several diseases. Finally, extracting enset starch is one of the most laborious tasks in all agriculture. Sweatshop labor in the cities seems a breeze compared with the "sweat-plot" tyranny enset fields impose.

PROSPECTS

It has been said that, "the main function of vegetables in semiarid areas should be to provide a means of survival in case of failure or partial failure of the staple cereals, which are more vulnerable to drought and insect attack." If this be true, then enset would seem the ideal candidate for famine insurance. Yet this enigmatic vegetable is a food resource in only one country, a fact indicating that it may not travel well, no matter what its promise. Ethiopia's neighbors, often beset by their own horrific droughts and famines, do not grow enset. Not even Ethiopians living in northern and eastern parts of the country seem particularly attracted to it. This may be due to the peculiar production, processing, and consumption characteristics of the plant. Enset is a perennial crop that needs 4 to 8 years to reach full maturity. The complex and arduous processing of its products requires special skill, tradition, and patience. And it is often not an instant hit with consumers. One needs time to begin to like enset food.

Within Africa

Although it might not find new countries to conquer, enset could certainly expand within Ethiopia. Apparently, it was eaten over a far greater area until just a century ago when it was abandoned and forgotten, perhaps due to misguided colonial influence.[5]

Beyond Africa

The plant seems to have no difficulty growing in lands beyond the seas and (at least in principle) Ethiopian immigrants in Israel and parts of the United States might try cultivating it. However, it seems unlikely that enset will ever make it onto the crop-production lists in any non-African nation. The immigrants are overwhelmingly from central and northern Ethiopia where enset as a food is unknown. And getting the plant to produce food takes time, and perhaps tradition.

USES

[5] Sadly, this lapse had fateful consequences. "The northern town of Lalibela, famous for its eleventh century rock-hewn churches, is also the site where thousands of people died as a result of the mid-1980s famine," write *The Tree Against Hunger* authors. "Some farmers in Lalibela grow a few enset plants near their houses in order to use the leaves to wrap bread for baking. Like other northern Ethiopian farmers, those farmers [we] contacted had no knowledge of enset as food."

Possibly no plant on earth can match this one for the number of products it provides poor people.

Greens When young and succulent, several enset parts can be boiled like cabbage or artichoke. The giant stem is actually fashioned out of overlapping layers of rolled up leaves, and the thick immature leaf stalks are cut into small pieces, boiled, and reportedly come out tasting like cooked celery. In addition, the immature pith can be extracted from inside the stem and boiled as a vegetable.

Flour The best quality enset food comes mainly from the stems of mature plants. The milky white pulp, known as bula, is obtained by laboriously scraping it off the inner leaf tissues. Most is eaten with milk in the form of an acidic porridge, which is considered a status food. Squeezing bula produces a milky liquid that can be concentrated and dried into a white powder. Dough made from this starch-filled flour is turned into many things, including enjera, porridge, and dumplings.

"Cheese" Whereas the whitest and cleanest pith samples are made into flour, the rest are put aside to ferment. Typically, the pasty pulp is placed in a deep pit and left for a few weeks or months. What emerges is a doughlike material called kocho, which, like a great cheddar, keeps for months or years without spoiling. More than 20 foods—yogurts, cakes, dumplings, porridges, and so forth—are made from it. Commonly, kocho is mixed with spices and butter. Some is chopped small and cooked with meat and cabbage. It is so useful and popular that many farmers have dug the fermentation pits inside their homes to foil thieves.

"Potato" Young enset corms are commonly cut up and cooked like potato, yam, or cassava. They can also be grated and added to the stem pith to form flour and kocho, as mentioned above.

Leaves Banana leaves are certainly big, but enset's are bigger. Up to five meters long and nearly a meter wide, they are employed as a sort of natural wrapper for bread, grain, meat, kocho, and many more foods. Practically everything leaving the village for the market goes wrapped this way. These huge flat sheets of vegetation also line the kocho pits. Moreover, dried leaves are commonly pulped to make cleaning rags, brushes, baby cushions, diapers, and trivets for supporting hot cooking pots. They are woven into baskets, mats, rain capes, and hats. Some are used as plates for serving food on special occasions and much of the enset leaf crop becomes bedding for man and beast.

Beyond all that, the giant green fronds are an important feedstuff, especially in the dry season when grasses tend to make themselves scarce.

Enset leaves are customarily hauled into the house to satisfy the cattle stalled there nightly for safety and for warmth.

The round and hollow stems (petioles) and woody midribs of these giant leaves are separated from the flat leaf tissue and burned as fuel, woven into mats, and made into other materials useful around the house. Insulation between layers of roof thatch is one example. Water pipes is another.

Fiber The process of separating the flour from the crude pulp yields a special byproduct: a strong threadlike material not unlike abaca. A world-renowned fiber (from another banana relative, in Asia), abaca withstands boiling water and has proven invaluable for making the tea bags now used worldwide. Each year Ethiopia's factories process about 600 tons of the enset counterpart, turning it into cordage, sacking, bags, ropes, mats, construction materials, and clothes.

Nurse Crop Enset is most commonly grown around houses. There, the plantation acts like a personalized forest, sheltering the family members, their plants, and their animals from wind and sun. Encompassing the homestead with a continuous canopy of vegetation is the goal of most growers. In fact, farmers go out of their way to get the canopy to close up quickly. Not incidentally, this provides an ecosystem conducive to the production of such things as garden greens and coffee. Farmers commonly plant sun-loving annuals such as maize and cabbage among younger enset plants, taking advantage of the sunlight before the canopy closes. But mostly they grow a range of shade-requiring species.

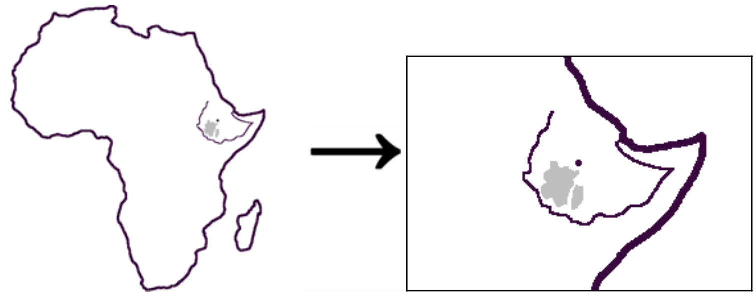
Ornamental With its thick, dark-green foliage, enset not only appeals to those living among it, but from a distance it provides an attractive patina to the Ethiopian landscape.

NUTRITION

Like cassava, sago, plantain, and some other staples, enset flour is little more than starch, with minimal fat, protein, vitamins. Each kilogram contains a mere 37 grams of protein. Enset-based diets thus need heavy supplementation. However, at least one mineral occurs in reasonable quantities: The calcium content is said to be higher than that of other roots and tubers.

Fermentation increases protein content and slightly raises the levels of essential amino acid. Indeed, the fermented pulp is said to contain more lysine than cereals have, but the methionine content remains low.

Despite the plant's dismal nutritional power, something about the household garden system benefits human health. In the 1990s a total of 6,636 children from four of Ethiopia's ecological zones were examined for signs of the blindness brought on by vitamin A deficiency. Sadly, beta-



General area of enset cultivation southwest of Addis Ababa (locations and boundaries approximate). Wild enset ranges from Sudan to Nigeria to South Africa. Although few outsiders have ever heard of it, this tree-like crop underpins the food supply in Ethiopia's densely populated southern highlands, where an estimated 10 million people consume it annually. (Map based on *Tree Against Hunger*, courtesy of AAAS.)

carotene levels were deficient in 10.4 percent of the children and low in 26.4 percent. A more unexpected finding, however, was that children from the enset zone had the highest beta-carotene concentrations of all. In their conclusion the researchers recommended that Ethiopia initiate a vitamin A deficiency control program, with the main emphasis being placed OUTSIDE the enset zone.

HORTICULTURE

Cultural practices vary between different localities, but virtually all enset is produced in small plots around the homestead. Compared to other crops the production involves many complex steps.

Planting is one of the most complex steps. Enset is propagated not by seed but by vegetative means. Trouble is, the plant has no vegetative part to use. However, in what is probably the key to the crop, ancient Ethiopians discovered that cutting out all the central tissue induces the smooth corm to burst out in buds. To bring this about, the farmer cuts the top off a young plant, slices out the corm's center, and packs soil and manure into the hole.[6] With its "heart" excised, the corm has no way to replace its leaves and flower stalk and, in a last-ditch attempt to reproduce it throws off as many as 200 buds around its edges. After a year, those buds sprout leaves and can be broken off. The resulting suckers, looking like ensets in a bonsai garden, are planted in nurseries, where, following another year or two, they turn into

[6] Because of dominance by this apical bud, lateral buds on the true stem do not usually develop; but once the apical bud is removed, these lateral buds form suckers around the periphery of the mother corm piece.

viable plants with all the size and qualities of their parent.

Managing the crop in the field is a second complex step. Again almost every locality has its own variant, but one common feature is a strange sort of "shifting cultivation" in which the plants are moved around like men on a chessboard. This seems to be an attempt to keep a canopy of leaves always sheltering the garden as well as to keep the bigger specimens from cannibalizing each other's nutrients and water. Some individual plants get moved once in their lifetime; others shift positions up to four times, at ever-wider spacing.

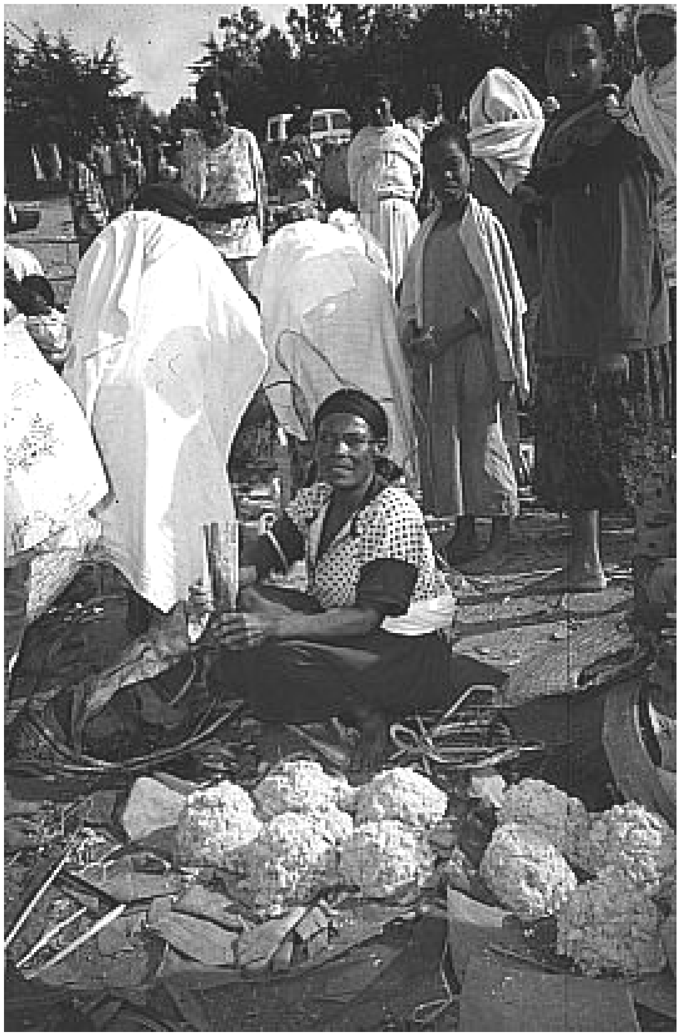
Harvesting is complex too. Some plants get cut down after two or three years (for the fresh corms); others are left for perhaps three times as long to generate the maximum amount of stem starch. All this variation in production allows the family to have a continuous food supply for years, if not forever. To outsiders used to the order of grain fields in places such as Kansas or New South Wales, however, it seems like a scene from some nightmare of cultivation chaos.

HARVESTING AND HANDLING

Although we've said that enset plants typically live 7 years, the lifespan depends on the altitude. In warm locations at low elevation ensets reach maturity in five, four, or even three years. In colder higher locations they can take ten or fifteen years. Once mature, the plants must be harvested because they then begin flowering, use up all the starch they've stored, and die.

Although the farmer normally harvests the plant just before it flowers and dies, it may be harvested anytime during the years the starch is building up in the stem and root. This is where the backbreaking labor comes in. The farmer cuts the pulp-filled stem or corm into strips using something like a machete, then scrapes out the pulp and juice using small bits of wood or bamboo. The task seems never-ending because each pass scrapes only a small sliver from the fibrous pulp.

Yields are difficult to evaluate because different plants are grown for different numbers of years, their spacing changes with time, and at various points they are interspersed with other species and other-sized enset plants. However, it has been estimated that the average family cultivates between 200 and 400 ensets in their household garden, consuming 10 to 20 per person per year. A normal-size mature plant is said to give 26 to 42 kg of food. In regions where enset is the staple crop, people consume 0.43 to 0.7 kg of kocho daily. According to those who recorded this fact, such an amount of kocho provides 860 to 1,400 calories, or between half and three-quarters of the food-energy typically consumed in rural Ethiopia.



A woman selling kocho at a local market. Note that enset leaves are used like plates or mats on which to display the product. Women are generally the exclusive marketers of enset food products. (Anita Spring)

LIMITATIONS

Diseases are collectively the most severe biological problem this crop faces. In several locations bacterial wilt is currently very threatening. It attacks right up to the moment the plants are ready to harvest. Nothing could be more mean sprited. The farmers become so devastated by the waste of

years of life, labor, and land that out of pure frustration they switch to crops that are less galling.

Enset is attacked also by root-knot nematodes, viruses, and fungi. During the early 1970s a fast-spreading fungus (*Fusarium oxysporum*) decimated enset and precipitated a famine. This fearsome fungus is related to others attacking bananas worldwide; luckily in this case the enset recovered.

Enset processing is an overall abhorrence. Not only is it tiresome and demoralizing, it is unhygienic. Someone has written that "without women to process enset, there would be no enset food produced and the plant would simply be an ornamental, as it is in other parts of Africa and Asia." That says a lot, and not just about the plant.

Lack of understanding is a big limitation as well. Until recent years the Ethiopian government emphasized more prestigious, profit-making, crops such as cereals. Only in 1997 was enset declared a National Crop, making it eligible for reasonable research and development funding.

NEXT STEPS

Following are a selection of possibilities that can move enset forward to better serve African needs.

Plant Health Bacterial wilt deserves top priority. On the surface, this bacterium should not be difficult to deal with. It is spread from plant to plant not by wind or water, but by the farmers themselves. Any object touching a contaminated plant or processed product (such as kocho) picks up the infection. Machetes and the little wooden scrapers are major culprits. Needed here is a public-health campaign aimed at making farmers keep their tools and plant materials clean of the infection. An especial need is to prevent the bacterium from spreading into the still uninfected regions. Another special need is to ensure that materials go to market only in wrappers untainted by wilt.

Beyond an education program there appear to be good possibilities for developing wilt-resistant enset plants. Already, some farmers have noted that certain clones tolerate the disease, while others revive rapidly after a bout with the bacterium.

Reducing Drudgery Several institutions have developed devices that reduce the tedium and time needed to process enset.[7] Few if any have had much impact. Women are beginning to use iron scrapers for decortication and cloth squeezers for bula, but there is still vast scope for reducing the damaging drudgery that devastates lives. Needed now is a concerted effort to develop and test:

[7] These include the Institute of Agricultural Research (at Nazaret and at Awassa), the Ministry of Agriculture, and Awassa College of Agriculture.

- a decorticater that separates pulp from the leaf-sheath;
- a pulverizer to grate the corm into fine pieces;
- a kneader to squeeze water from fermented kocho; and
- a shredder to chop the fiber in the fermented kocho.

Indeed, there is also potential for all such devices to be disseminated as part of a cottage-industry development package that updates and simplifies the entire process of enset production. Presumably, most of the devices would be manually operated, but the potential for mechanized processing by portable or village-based power-driven scrapers, pulverizers, kneaders, and shredders should not be overlooked. This whole area of development needs open-minded innovators from mechanical engineers to food technologists to tinkerers of the handyman subspecies.

Livestock In *The Tree Against Hunger*, the authors draw attention to the critical role livestock play in enset farming. Cattle provide many vital things: manure to make the trees grow, milk and meat to balance the diet, power for plowing, and cash for times of need. This connection is not well enough appreciated in high places. "All too often," say the authors, "researchers and extensionists ignore the importance of livestock in maintaining the productivity (and with respect to enset, the sustainability) of agricultural systems."

Thus one of the best sciences for bettering this plant's production may be animal science. The authors state that positive effects on enset cultivation systems would come from improving animal nutrition and health, improving breeds, training farmers to cull herds, and providing information, capital, and planting materials to improve pastures and forages. The farmers seem likely to be very receptive. Even now, they commonly ask for better veterinary help.

Further, turning enset leaves into silage and feed concentrates has not been explored, but it could have great potential for enhancing feed for livestock.

Balancing the Diet Beyond raising the availability of milk and meat, the enset system's overall nutritional output could be improved by increasing the production of other vegetables. Grain legumes such as common bean, lentil, and chickpea have been suggested, but there must be many more possibilities. Although the thrust should be less toward research and more toward extension, there is vast scope here for far-reaching collaborations between nutritionists and horticulturists of many backgrounds.

Marketing Assistance Enset is a powerful tool for poverty reduction and prevention. Beyond being a subsistence resource, it is a commercial resource

of note. Thousands of women sell enset foods to make money for household supplies such as kerosene and salt. One "cursory survey" of the main Addis Ababa market, Mercato, revealed over 120 women selling kocho and bula. In addition, both women and men sell leaves, mats, rope, construction materials, and other non-food products made from the enset plant.

Informal interviews and observations at Addis Ababa restaurants indicate establishments often run out of quality kocho. They yearn for more. The shortages are blamed on poorly developed marketing and transport systems, but many related issues also need improvement, including storage facilities, quality assurance, capital, and packaging.

New Locations People in the regions of Tigray and Amhara (e.g., Gondar and Wollo) don't eat enset, but the plant occurs all around them, and they wrap dough in the leaves while baking their bread. Although attempts have been made to inform and encourage farmers here to grow the crop for food, more efforts are needed. Taken overall, enset could perhaps double in area, and prime locations for expansion are in these regions, which are vulnerable to droughts and disasters and where the plant occurs but is not used.

As far as locations outside Ethiopia are concerned, the crop might at first sight seem very promising. Wild enset already grows from Sudan in the north and Nigeria in the west, all the way to Angola and South Africa in the south. Nonetheless, its chances of being cultivated for food outside Ethiopia are probably slim. Not only are the methods of turning it into food unknown in those locations, they are probably difficult to introduce. Nonetheless, exploratory efforts are warranted. If the preliminary hurdles can be overcome, then this species might provide the long dreamed of stable, reliable, sustainable farming system much of drought-threatened Africa desperately needs. Its potential is mainly for areas that do well most years, only to suffer devastating periodic desiccation.

Food Technology There is a great need for food technologists to involve themselves with the problems surrounding enset. They are needed, for example, to make the processing hygenic and reliable. A starter (called gamacho) is used to begin the fermentation of kocho, but it is usually just a sample scooped out of the last batch. Partly for this reason, kocho is a variable foodstuff, not quite to be trusted. Food technologists should investigate this fermentation, create pure cultures, and adopt appropriate techniques from cheesemakers. In this way, quality kocho of verifiable safety and stability could be produced routinely. That will surely open up the big city markets.

Another role for food scientists is to identify the enset's nutritional components. For example, at present no one knows much about the protein's actual amino-acid profile.

Horticultural Development Although research on enset has sputtered along since at least the early 1960s, it has lacked continuity and direction. Thus, the door remains wide open to investigation on a dozen fronts. Examples provided by another reviewer include: the effects on growth and yield of different clones; plant spacing, and duration at a given spacing; transplanting methods; manure and/or fertilizer amendments; propagation techniques; and environmental conditions (i.e., temperature, water, and sunlight). All these have yet to be pinned down.

Much of what is needed is basic research. For instance, corm rot, sheath rot, and dead-heart leaf rot are all diseases for which the actual pathogen remains unidentified.

One special challenge is to speed up the plant's growth. The best time to harvest it is just when flowering begins, but exactly when flowering occurs depends upon climate, clone, and management. Currently, it varies from 3 to 15 years but is most commonly 6 or 7 years. A broad approach, involving everything from clone selection to field management could possibly cut that time in half and make the farmers all the happier, not to mention twice as safe from failure due to drought or disease.

SPECIES INFORMATION

Botanical Name *Ensete ventricosum* (Welw.) Cheesman

Synonyms *Musa ensete*, *Ensete edule*, *Musa ventricosum*

Family Musaceae

Common Names

Ethiopia: enset, guna-gunaf (Amhara), asat (Gurage), weise (Kambata), and wassa (Sidama), kocho (G), koda (Am/Sodo/Oromo), werke, wesa (Oromo), [*aquimi (Ari*)]

English: enset, ensete, Abyssinian banana, wild banana, false banana

Malawi: Chizuzu (Ch)

South Africa: Afirikaanse wilde-piesang (Afrikaans), motholo (Pedi), mulala (Venda)

Kenya: ndizi mwitu (Swahili), makulutui (Ka)

Zimbabwe: mubhanana mufigu, dzoro, hovha

Description

This species looks quite like a banana plant. Enset, however, is usually larger, its leaves more erect, and shaped somewhat more like a lance head. They are spirally arranged, and bright green with a striking red midrib.

What would appear to be the trunk in most plants is actually three distinct sections. A short length at ground level is the only part of the plant

that is true botanical stem. Leaf sheaths emerging from this core form a tightly wrapped pseudostem, at the top of which the leaves unfurl into the classic "banana" form. This stem-like portion, up to three meters long, contains both edible pulp and quality fiber. And below the soil line is an enlarged corm, up to 0.7 meters or more in length and diameter, also full of starches. A fibrous rooting system grows out from the corm. While banana plants naturally form suckers or clusters of plants at the base, enset plants do not.

This is a monocarpic plant. Like century plant and bamboo, it bears fruit only once, and then quickly dies of exhaustion. It may live 15 years before the big fat flower stalk emerges from the top of the plant. Once out, it forms a massive, pendulous spike. Surely one of the world's biggest flowers, it is 2 to 3m long, and hangs downward from a stalk in the center of the plant. The individual florets are cream colored, with a single petal, enclosed in large maroon bracts. The fruits resemble small bananas, having a yellow skin, but they are filled with a mass of hard, small pea-like seeds.

Distribution

Few details about enset's overall distribution are known.

Within Africa The wild type occurs from Nigeria in West Africa through the central to the southern parts of the continent, including Transvaal, Angola, Zimbabwe, Mozambique. However, Ethiopia is the only place where the species has been domesticated. Suggestions that the plant was tamed as far back as 10,000 years ago have been presented. The wild form occurs at lower altitudes than the present area of enset cultivation in Ethiopia.

Beyond Africa Enset is sometimes cultivated as an ornamental in Asia and other places. New Zealand is one country that it reportedly beautifies.

Horticultural Varieties

There are no formal varieties but farmers recognize more than 50 different clones, and normally grow several together in the same field. Certain ones are renowned for their quality corms.

Environmental Requirements

Detailed studies on the effects of environmental constraints such as temperature and water availability have not been conducted. Therefore, all claims as to enset's range of adaptation are suspect.

Rainfall Most enset-growing areas receive annual rainfall of between 1,100 and 1,500 mm, the majority of which falls between March and

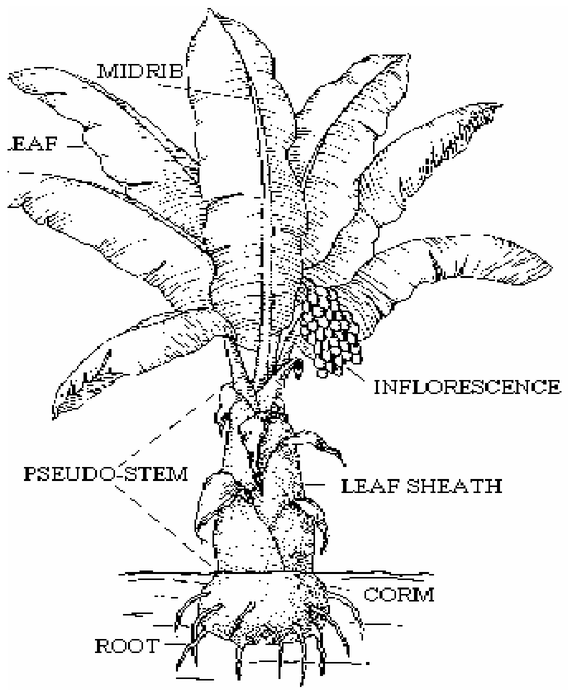
September. This amount may not be necessary, but it is known that the crop fails in consistently dry environments with short rainy seasons.

Altitude Enset is planted at altitudes ranging from 1,100 to more than 3,000 m. It is said to grow best between 2,000 and 2,750 m.

Low Temperature The average temperature of enset growing areas is between 10 and 21°C, with relative humidity of 63 to 80 percent. The optimal temperature range has been put at 18 to 28°C. From preliminary observations it can be said that enset cannot tolerate freezing. Frost damage on upper leaves is commonly observed above 2,800 m elevation, and serious stunting occurs above 3,000 m.

High Temperature Any constraint to enset plant growth probably is more related to available water than to heat. It is possible, however, that the crop is more subtropical than tropical because the current production areas—while close to the equator—are so high in the sky.

Soil Enset grows well in most soil types, as long as they are sufficiently fertile. Neither roots nor corms tolerate waterlogging for long. For that reason, the crop is usually grown in well-drained soils without high watertables. The ideal soil seems to be a moderately acidic to slightly alkaline (pH 5.6 to 7.3).


MIDRIB
LEAF
INFLORESCENCE
PSEUDO-STEM
LEAF SHEATH
CORM
ROOT


S.J.H.

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LABLAB

In parts of tropical Asia lablab is a popular, even important, food. For the rural population of southern India, for instance, this crop supplies a considerable proportion of the protein in the daily diet. Both there and in other regions of India young lablab pods are widely consumed as a vegetable—boiled like French beans, dumped into curries…things like that. Sometimes the immature seeds are extracted from the green pods and boiled or roasted for dinner.

And India is not the only tropical Asian nation to exploit lablab. Farther east, the mature seeds are treated like soybeans: boiled and processed into tofu or fermented into tempeh. The sprouts are said to compare in flavor and quality with those of mung bean. The leaves and flowers are consumed like spinach (most notably in a famous Indonesian dish that goes by the generalized name of "lablab"). And the seeds have been processed like soybean into a protein concentrate.

The strange thing about this nutritional cornucopia of Asia is that it is, by origin, African. Stranger still is the fact that the plant is almost unknown to the present-day inhabitants of its native continent. Whereas it certainly can be grown in almost all regions of Subsaharan Africa, lablab's use as a vegetable seems all but unknown and has not been pursued vigorously in any of them until, perhaps, recent years.

"Shameful" certainly seems to be the right word for this. The fact that little or no help is being provided this food plant in its home territory, where malnutrition is chronic, is more than distressing. Making the situation particularly ironic is the reality that this local counterpart of the soybean possesses qualities that could prove exceptionally valuable for Africa's rural development and environmental stability. Beyond being a prolific food producer, lablab thrives on relatively acid soil of low fertility and high aluminum toxicity. Its penetrating roots draw nourishment from deep below the surface. And this vigorous legume improves the land's nitrogen content through the action of the highly active beneficial bacteria residing in nodules on its roots.

Lablab is also suited to poor-people's needs. The plant is simple to establish and easy to manage under subsistence conditions. It gives high yields. It resists droughts that affect leguminous crops that farmers now

struggle to produce in tropical Africa. And, generally speaking, it stays green and productive well into—even all through—the dry season, a period in the monsoonal tropics when food is hard to come by and the possibility of hunger looms large.

Tropical botany publications typically describe lablab as being of "probable Asian origin." On the surface that seems correct; the plant certainly finds its greatest development in South Asia and Southeast Asia. However, the center of diversity of genus *Lablab* is Africa, so there should be little uncertainty over its ultimate biological birthplace. Indeed, lablab's wild ancestor is even now scattered across, and is clearly a native to, much of tropical Africa.[1] Sometime before history was recorded one or more observant souls came to appreciate the wild species' potential and hauled seed samples across the Indian Ocean. In its new Subcontinental home people seized on the plant and down the many centuries since then developed it as a garden crop.

Having being cultivated since ancient times those food types have now reached a high degree of development in Asia. They are the main focus of this chapter. It is time to bring those vegetables home again and put them to use in Africa itself.

However, in a parallel and relatively recent endeavor, non-food varieties of lablab have been selected and advanced as forage and green manure crops. These coarser, more robust, and less palatable types, are planted in various parts of the tropics—including parts of Africa—mainly to produce forage. As a result, forage specialists these days consider lablab among their most useful tools. Managers of coconut, rubber, and oil palm plantations revere the species also, knowing from long experience that it is one of the most valuable, trouble-free, and reliable of all leguminous herbs for suppressing weeds and rejuvenating worn out soils.

It should be understood that modern horticultural science has not entirely neglected lablab, at least outside Africa. In India, for example, a series of cultivated varieties (numbered Co-1 through Co-9) have been developed as green vegetable crops. One of them (Co-9) is said to average 7,500 kg of pods per hectare in the southern state of Tamil Nadu. It is quick maturing (120 days), with broad, flat pods, and an attractive light-green color as well as good flavor, aroma, and texture.

In Australia (notably, northern New South Wales and southern Queensland) another promising food variety is becoming quite widely used. 'Koala' is a short season, early maturing lablab, suitable for food (and fodder) production. Its developers claim that its white-to-cream colored

[1] One of Africa's most knowledgeable legume botanists leaves no doubt about the point: "*Lablab purpureus* is unquestionably of African origin," Bernard Verdcourt wrote to us some years back. "The only wild taxon known is subspecies *uncinatus*, which is very widespread in tropical Africa."

In Asia lablab is a popular foodstuff. For rural peoples of southern India, for instance, its pods and seeds supply much of the daily protein. The strange thing is that lablab is African. Stranger still is the fact that it is almost unknown to present-day Africa. Yet this local counterpart of the soybean possesses qualities that could prove exceptionally valuable for nutritional well-being, rural development, and environmental stability almost throughout its continent of origin. Glenn Kopp/Missouri Botanical PlantFinder mobot.org/gardeninghelp/plantfinder

grain is suitable even for export, and they dream of sending shiploads of it to Asia like a southern-hemisphere soybean. Commercial crops of 'Koala' have yielded up to 2 tons of grain per hectare (without irrigation but under otherwise good conditions). Trials show that on average it produces 20 percent more grain per hectare in subtropical Australia than does mung bean.

Beyond all its uses for food and fodder, the plant can be used advantageously to provide organic matter and fix soil nitrogen; thereby improving subsequent crop yields in a cheap and environmentally friendly manner. It is not inconceivable that it could become an essential part of certain sustainable farming systems.

Taken all round, lablab might seem not too far removed from some botanical diamond in the rough. And that appearance is not untrue. Moreover, it is remarkably adaptable and so useful that it can be employed without waiting for the ultimate benefits that will come from agronomic cutting and polishing.

PROSPECTS

There seems no reason why the refined kitchen-garden types as well as the coarse field types (not to mention specimens combining qualities of each) should not take off vigorously in Africa. Indeed, they could be employed widely and with due dispatch. At present, Africa does not use the vegetable type to any great degree, but the forage types are already there to provide a foundation for progress and understanding. Moreover, smallholder farmers are beginning to use legumes in rotations, and multipurpose legumes like lablab are promising for land restoration and sustainable agricultural systems in most parts of the continent.

Within Africa

Strains of lablab capable of thriving under the diversity of conditions occurring across most of Africa can be found but the more refined types for food use probably need to be selected for specific sites.

Humid Areas Excellent. The plant thrives under high heat and humidity. However, in hot, moist climates certain fungal diseases are a concern.

Dry Areas Excellent. A well-established lablab plant's root system often penetrates into water sources more than 2 m deep, permitting luxurious growth to persist long after the rains have ended and the surface soil is parched. For this reason, the crop can have a long production season and can provide food, fodder, and soil protection long after other herbaceous species have dried and died.[2]

[2] A reviewer wrote: "Certainly they are drought tolerant, have good root depth and in my

Upland Areas Excellent. Lablab is already grown in the eastern African highlands. And in Zimbabwe it is doing very well at an altitude of 1,500m.[3]

Beyond Africa

Excellent. The plant is already widespread throughout the tropics, but it offers so many uses, so many varieties, and such wide adaptability that it has by no means reached its potential even in places like South India that know it best. The plant also has potential in subtropical and warm temperate regions worldwide, as has been demonstrated in eastern Australia in recent decades.

USES

Lablab can be put to so many overlapping uses that it is hard to summarize them clearly. A selection of examples follows:

Pods The young pods of the culinary type are popular vegetables in India, Indonesia, the Philippines, and elsewhere in the Asian tropics. They are eaten like green beans or snow peas.

Seeds In India the dried seeds are split like lentils and used in making dhal, the major protein source for millions of the populace. They are also sprouted, soaked in water, shelled, boiled, and smashed into a paste, which is fried with spices and used as a condiment. Dried seeds are also fed to livestock.

In Africa, lablab seeds are cooked in any of the ways commonly used for beans: boiled with maize, ground and fried, or added to soups. It is included in the traditional Kikuyu dish called imo, a mixture including such things as maize, beans, bananas, potatoes or green vegetables all boiled down into a tasty paste. In Egypt lablab seeds are sometimes substituted for broad beans in preparing the fried bean cake called tanniah.

Leaves The leaves are occasionally used as a potherb, although they are said to be less palatable and less popular than cowpea leaves.

Environmental Protection As mentioned, the field-type lablabs are effective for land restoration.[4] They can be grown alone, interplanted with field crops, or included in crop rotations. They make a good cover crop in

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work in Zimbabwe, are doing very very well in 800mm rainfall at 1500m."

[3] Information from Bruce Pengelly.

[4] Lablab is the green manure which is grown in rotation with cotton and sorghum in the Gezira in Sudan—Africa's biggest agricultural enterprise—and is the last crop in the rotation, after which the land is bare fallowed for a season.

With a crude-protein content of 20-28 percent, lablab seeds are worth considering in malnutrition prevention programs. In addition the amino acids are moderately well balanced, with an especially high lysine content, which means that they help balance out diets that are heavy on the staples. The seeds are also a good source of energy. (Lori Alden, *The Cook's Thesaurus*)

coffee and coconut plantations, fruit orchards, and more. They are often planted as a second crop in rice fields after the harvest of paddy. In each case, they may be grazed after the pods have been harvested for food.

Forage Lablab is so fast growing that grazing or haymaking can begin 7 to 10 weeks after sowing. The plant withstands severe cutting. Cattle, sheep, goats, and pigs eat it avidly. Fodder yields of 5 to 10 tons per hectare are said to be normal. Hay from the whole plant (if cut at a young, leafy stage) is nutritionally comparable to alfalfa, although somewhat less digestible. When chopped, the plant produces good silage. Incorporating living lablab into grass pastures improves the quality, palatability, and digestibility.

Other Uses Nurserymen in the United States sell lablab as an ornamental. Certain varieties of what they call "hyacinth bean" are renowned for their long, bright, showy, purple blossoms. In a very clever initiative, the Government of Guyana encourages city dwellers to grow ornamental varieties along fence lines to form hedges that provide protein for the family table as well as a pretty prospect for the passerby. It is notable that lablab is suited to urban use.

NUTRITION

Comparing the crude-protein contents of lablab and dried seeds of common legumes shows that, at 20-28 percent, lablab is exceptionally

nutritious. In addition, amino acids are moderately well balanced, with especially high lysine content (6-7 percent), which means that lablab seeds complement cereal diets well. However, methionine deficiency (0.65 percent in one count) is reported, so in this regard the protein profile is not perfect.

The seeds, in addition to contributing relatively good quality protein, are also a good source of energy. However, as with many other pulses, the lablab seed contains antinutritional factors, which must be taken into account (see later).

The leaves also are rich in protein (up to 28 percent) and, at least among legumes, they are one of the best sources of iron (155 mg per 100 g of leaves, dry weight). Whole-plant protein ranges from 14 to 22 percent, depending on the season and the lushness of the plants.

HORTICULTURE

The lablab plant looks somewhat like cowpea and can be grown in a like manner. Although in the tropics the plant persists two or three years (if well watered) it mostly acts as an annual. When grown for food, lablab is usually sown in rows, either alone or mixed with crops such as maize, beans, potatoes, peas, and bananas. Normally, the seeds are directly planted into the soil of the field, kitchen garden, or fence line where the crop will grow. Germination is rapid, but establishing a good stand requires continuous soil moisture. Typically, several seeds are sown in each hole and the seedlings are left unthinned. The resulting dense growth tends to suffocate weeds.

Lablab is sometimes sown together with annuals such as sorghum and cotton. It suppresses weeds, helps protect exposed land, and contributes food after the primary crop has been harvested. It is normally left to its own devices, although weeding during the establishment phase may be necessary. The climbing varieties often support themselves on the convenient stems of taller plants, such as maize or sorghum.

The growth period can vary from approximately 75 to 300 days. In India, Co-1 begins to bear pods approximately 60-65 days after sowing and continues for 90 to 100 days. Other improved cultivars such as Co-6, Co-7, and Co-8, which can be grown year-round, produce pods 60 days after sowing and continue up to 120 days in South India. Mature seeds are normally harvested 150 to 210 days after sowing, but this depends upon the cultivar and the season of sowing (i.e. daylength regime). In equable tropical climates and with good management the plant can yield continuously for two or three years if desired.

Lablab nodulates easily—either with its specific rhizobia or with the cowpea-type, which occurs widely in tropical soils.

Compared with cowpea, the plant is more resistant to root diseases and more productive. In fact, certain types reportedly produce twice the herbage of cowpea. However, lablab stems are stronger, more fibrous, and less palatable than their cowpea counterparts.

HARVESTING AND HANDLING

When grown as a vegetable the green pods are picked by hand when they reach a reasonable size, usually when the seeds are about three-quarters formed. The plants are subsequently picked at intervals of several days, the pods being cleaned, graded for size, and packed in baskets for hauling to market. In the heat of the tropics both the green pods and the immature beans have relatively short shelf lives. The average yield of green pods in India has been recorded as varying from 2.6 to 4.5 tons per hectare.

Species of the genus *Lablab* tend to hold their seeds; they are less likely to dehisce immediately on maturity than many other legumes. Thus shattering is not a huge problem, and when grown for seed, lablab can be mechanically harvested. After drying in the sun the mature pods are beaten (using sticks or machines) to separate the dried seeds.

When grown as a forage, lablab can provide both high seed yields *and* high biomass yields. In experimental trials in northern Australia, four accessions yielded over 4 tons of dry seed per hectare.[5] One of these, a commercially registered variety called 'Highworth,' consistently provides over 1.5 tons of seed per hectare in commercial cultivation as well as 5-11 tons (dry weight) of forage. The forage has a protein content up to 22 percent and production is fast. In Queensland, lablab pastures are ready for grazing 60 to 80 days after planting, and optimum stocking with cattle is about 1.5 animals per hectare.

LIMITATIONS

Despite resisting attacks from Mexican bean beetles and other insects that devastate common bean, lablab is not immune to pests. Insects of the leaves, pods, flowers, and soil have proven serious in northern Australia, for example. And in Africa the neat little holes drilled by bruchid beetles are often seen in lablab seed.

Similarly, although generally reported to be fairly resistant to disease, lablab is not immune from attack. Some cultivars, for instance, have proven susceptible to bean rust and fungal rot.

Root-knot nematodes also can afflict this crop, sometimes seriously. And, in some African areas, the parasitic weed striga sucks the plant's juices and energy with as much gusto as on other crop species.

The mature seeds (especially dark-colored ones) must be boiled before eating. Like most soybeans, they contain a trypsin inhibitor that is broken down by heat as well as a cyanogenic glucoside that is leached out by the cooking water.

At least in theory a vigorous plant like this carries the possibility of invasiveness. However, there are no reports of serious problems in this

[5] Information supplied by Ian Wood.

regard. Indeed, lablab's palatability to cattle, goats, and other herbivores helps lessen the risk of it becoming a problem.

Lablab provides a very dense cover but not right on the surface of the soil. Beneath the canopy there is enough space for water to wash through and (especially on sloping land) cause erosion.

NEXT STEPS

Though moderately well known as a resource for tropical agricultural systems, lablab is far from being used to its full potential. For purposes of improving the situation specifically in Africa, one can conceive of many activities, including the following.

Africa-Wide Thrust Because of its many outstanding qualities, the plant is recommended for immediate use in tropical Africa as a pulse, green vegetable, green manure, and forage. This is worthy of a coordinated—or at least an international effort.

Farmer Survey From the start, it would be wise to identify who might grow lablab and why. It might take off not as a food crop but as a dual-purpose plant—for food-and-forage, perhaps, or food-and-soil fertility. Finding local preferences might best be achieved *with* farmers. The crop will be new to them but their ideas about preferred varieties and uses would come out as the research progresses.[6]

Also from the start it would be good to identify not only farming-system opportunities but also taste-testing components (leaves, pods, grain) and then evaluation of key types of plants for systems. Africa does not use the vegetable type to any great degree. But, as noted, the forage types are already there and smallholder farmers have begun using multipurpose legumes in rotations in recent years.

Seed Supply In many local African areas where lablab could be beneficial, there is no way people can get started for the sole reason there is no source of seed. Rural NGOs, companies, farmer organizations, and others involved in seed production and supply should adopt lablab. With this dual-purpose legume getting farmers to use the seed should not be a problem. What is needed is to identify the best seeds for the locality, get them farmer-tested, then encourage on-farm seed production and storage for subsequent seasons.

In a related vein, key work is needed to identify core seed collections. A

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[6] A reviewer wrote: "Sometimes these trials are very illuminating. In South Africa, we thought farmers would like white or light seeded lablab varieties. Not so. They wanted dark varieties—not for taste, but because when cooked the white seeded lines turned to mush too easily."

The forms of lablab that have been developed as green vegetables are promising profit-makers, producing huge yields (up to 7.5 tons per hectare) of pods that look and taste good, and producing them quite quickly (4 months). In addition, the dry seeds are becoming commercially important in Australia, where it is claimed that they are even suitable for export, like some kind of southern-hemisphere soybean. (J.H. Wildin)

recent paper describes the available germplasm and its diversity.[7] One of the world's largest lablab-seed collections is at the International Livestock Centre in Addis Ababa. And a seed collection in Kenya was the source of the lablabs now widely used in Australia.

Sustainable-Agriculture Projects Now is the time to incorporate lablab into sustainable-agriculture projects Africa-wide. In particular, trials are needed to identify best varieties and best practices to use this legume in smallholder farmings systems. One example: integrating lablab within cereal-based systems such as maize or rice, which could reduce the need for inputs of inorganic fertilizer.

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[7] Pengelly, B.C. and B.L Maass. 2001. *Lablab purpureus* (L.) Sweet–diversity, potential use and determination of a core collection of this multi-purpose tropical legume. *Genetic Resources and Crop Evolution* 48:261-272.

It should be recognized that legumes generally add little organic matter to soils. Their litter is broken down too easily and too quickly. In this regard, lablab is no exception. Nonetheless, trials are needed, and they should incorporate more than just this species. Mucuna, perennial soybean, jackbean, and other potential competitors should be included for comparison. Some will be better than lablab in some situations. Mucuna, for example, is less susceptible to insects than lablab, so in a humid environment it will probably be a better choice for producing green manure.

Demonstrations To overcome farmers' reluctance to adopt any new practice, demonstrations involving lablab should be established across Africa. These might well be established on farms, allowing select farmers to demonstrate and sell the resulting seeds to their neighbors. An alternative approach is to use participatory on-farm lablab research, focusing on agronomy and taste-tests for grain and vegetable use.

Horticultural Development Despite lablab's widespread occurrence, little agronomic improvement has been reported. There is need for research into genetics and breeding for faster-maturing varieties with better and more dependable yields as well as for improved resistance to pests and diseases. One target might be lablabs that mature their pods or seeds uniformly together, making them attractive for commercial harvest. Another target might be lablabs that mature over time, so as to supply pods and leaves to the family diet for weeks or months.

Of course, before embarking on plant improvement researchers should locate the types farmers have selected over the past 3,000 years. The diversity in the existing landraces is already remarkable.

Once seed types are selected, then research and testing of management practices, including fertilizer requirements, time of planting, and plant populations for specific products (seed, forage, hay, or green manure) should be done. The impact on soil nitrogen and soil organic matter should be included, too.

Forage We think that farmers will jump at the chance to grow lablab when they see how productive it is and how much their livestock love it. But in developing forage types, attention should be given to several special features: dry matter yield and its distribution through the year, palatability and feeding value, and compatibility as an intercrop with crop species to improve stover/lablab grazing quality.

Food Technology Research into the feeding value of the seeds for humans and livestock (not overlooking poultry and pigs) is also needed. Methods to reduce or remove the antinutrition factors, either by processing or by plant breeding, are needed. Such aspects as processing the seeds into

protein concentrates for livestock, poultry, and human foods, and the functional and chemical properties of the protein, similarly deserve attention.

Commercial Operations Although the lablab now finds its greatest use in small-scale agriculture, its potential for large-scale mechanized production of protein seems impressive. Lablab thrives in the monsoonal tropics, a region where soybean fares poorly. The 'Highworth' variety—which is grown in Australia but actually hails from Kenya—shows that the crop can be suited to mechanical harvesting and production. Research along these lines is needed for possible large-scale rural development projects.

Torture Tests Because of this extremely adaptable species' potential to help marginal environments, varieties should be further tested for their outer limits of tolerance to aridity as well as to acid-, alkaline-, saline-, high-alumina-, and nutrient-deficient soils. Production levels will fall off in such areas but the value to human life might nonetheless be all the greater.

SPECIES INFORMATION

Botanical Name *Lablab purpureus* (L.) Sweet

Synonyms *Dolichos lablab* L. and *Lablab niger* Medik[8].

Family Leguminoseae. Subfamily: Papilionoideae.

Common Names Almost every country (indeed every Indian province) uses a different common name. A few in widespread use are:

English: bonavist, chicharos, chink, Egyptian bean, Indian bean, hyacinth bean
India: seem, sim, pharao, val, anunula, ararai, chapprada, chikkudu, field bean, mochair, parta
East Africa: fiwi
Sudan: lubia bean, kashrengeig
Ethiopia: amora-guaya
Philippines: agaya, apikak, batao, hab
Indonesia: kerana
Thailand: tua nang
Malaysia: kara-karci
Myanmar: pegyi

[8] The literature contains at least 26 separate botanical names for what now seem to be different forms of this plant. Many articles published in recent decades use the names *Dolichos lablab* and *Lablab niger*.

Description

The wild germplasm seems to be always perennial, but over the past few thousand years the landraces have been selected to be mainly annuals. Thus, most lablab landraces today are true annuals, but they will perennate if their seed production is curtailed.

Varieties differ in many characteristics: The growth habit may be bunch, spreading, or climbing. The flowers may be white, purple, pink, or blue. The pods may be short and half-moon shaped or long and thin. The seeds, although usually brown or black, may be cream, white, red, or speckled. The pods contain 3 to 6 seeds and are up to 15 cm long. They are generally oblong, curved and flat, and have wavy margins and pronounced beaks. Each seed has a prominent white hilum.

The plant is vigorous and the climbing type can grow 5 to 6 m tall. In most varieties the inflorescence is an erect, long stalked raceme held high above the foliage.

Distribution

These days, lablab is found in warm regions worldwide.

Within Africa. Lablab's wild ancestor grows in hilly areas and coastal lowlands in southern, eastern, and western Africa. Its beans are small and apparently are not eaten. The cultivated form is known in Egypt, Sudan, and both East and West Africa.

Beyond Africa Lablab is most widely grown in South Asia and Southeast Asia (for instance, Malaysia, Indonesia, the Philippines, and Papua New Guinea). It is also known in the Caribbean, Central America, and the tropical zones of South America.

Horticultural Varieties

Although there are few formal varieties, lablab occurs in two botanical types. The garden type is twining and is grown on supports. It is late maturing and is employed mainly as a green vegetable. The field type is erect and bushy. It matures earlier but cannot be used as a green vegetable because even the green pods are fibrous and have an unpleasant smell. Over 200 genotypes are recognized. Despite the wealth of available germplasm, only a handful of registered commercial varieties are known in the countries that now cultivate the lablab.

Environmental Requirements

This is such an adaptable species that there are varieties for most kinds of conditions and locales. Speaking generally, however, the following are its

environmental requirements.

Daylength The plant is sensitive to daylength. Most genotypes require short days to initiate flowering, but long-day cultivars exist as well.

Rainfall Lablab is suitable for growing as a rain-fed crop where the average annual rainfall is 600-900 mm. In India it is successfully grown commercially, with supplementary irrigation, in areas with a rainfall as low as 400 mm. It requires adequate moisture during the early stages of growth, after which its deep roots enable it to exploit residual soil moisture. When grown as a market-garden crop for the production of the immature pods it requires watering or frequent rains throughout its growing period. Seed production can be a problem in regions with high humidity.

Altitude Locations up to and beyond 2,000 m have proved suitable for economic production, at least in equatorial nations such as Papua New Guinea.

Low Temperature For optimum results, a warm, equable climate is required, with average temperatures between 18 and 30°C. Many lablab types withstand frost for a limited period, although it is liable to cause leaf damage. Lablab is both self- and bee-pollinated, and cooler weather at flowering time can affect seed-set.

High Temperature Most—perhaps all—cultivars tolerate exceptional heat.

Soil The plant survives on a wide variety of soil types, provided they are well drained. It is reported to do particularly well on sandy loams that are slightly acid (pH 6.5), but in Brazil it thrives on heavy clays that are quite acid (pH 5.0). It cannot tolerate waterlogged or salty conditions. Little is known of any fertilizer requirements, but the plant reportedly responds to phosphate and potash. In experiments at Beltsville, Maryland, it grew well in soils ranging from acid to alkaline (pH 4.4 to 7.8) as well as in aluminous soils deadly toxic to most crops because of their level of soluble aluminum.[9]

[9] Information supplied by C.D. Foy.

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LOCUST BEAN

The West African locust looks nothing like what Westerners might consider a vegetable plant to be. It is a tree. A true Jack-and-the-beanstalk kind of crop, it is indeed related to beans, albeit distantly. It often grows more than 20 meters tall, and people harvest all the pods they can get, sometimes climbing all the way to the top.

Outsiders might dismiss this as a tall tale, but they'd be wrong. Locust combines in a single species Africa's two greatest needs: food and tree cover. More locusts mean more food *and* more trees, which add up to more hope for a better continent.

Botanists named this plant genus *Parkia* in honor of Mungo Park, one of the first Europeans to record it. This intrepid Scottish surgeon-naturalist, who drown in distress attempting to unravel the course of the Niger River, would even now be hardly displeased with the honor. Two centuries on, his namesake plant still plays a vital role in the village and nomadic life of rural peoples living throughout the northern and western savanna regions.

Locust beans are attractive savanna trees, with dramatically spreading crowns and clusters of globular bright red flowers dangling like holiday decorations on long stalks. And they produce many benefits.

For one thing, they produce fruit. Numerous large pods, up to as long as your forearm and wider than your thumb, emerge all over the spreading crown, dangling like the fingers of a green or brown giant. Inside each pod is a yellow or orange dryish pulp. People like it, and no wonder: it can be half sugar and very sweet to the taste, almost like a desert. This mealy delight can make a useful baby food but for many children it may be the main—if not the only—dish, depending on what is left in the family's granary. It is also made into colorful and refreshing drinks. And it is dried down into a white or yellowish powder that can be stored for later use, at which time it is commonly sprinkled over rice or meat.

But sugary pulp is not this tree's main gift. Instead, it is the seeds enclosed within it that are the most prized product. These are a regular part of people's diet and, throughout much of West Africa, they also turn into lifesavers in times of famine. They contain about 30 percent protein, 20 percent fat, 12 percent sugar, 15 percent starch, and 12 percent fiber, as well

as vitamins and minerals such as calcium and iron. In sum, they are about as balanced and concentrated a food as could be devised. Add the fact that they mature in the dry season, the traditional "hungry time," and their value as emergency food becomes plain.

Reliability is key. Even when drought has seared the landscape, the products from this deep-rooted tree continue appearing on schedule. This is how they save lives. Indeed, they are so good at it that Muslim African tradition claims the tree to be a gift from Heaven—actually brought to Africa by the Prophet Himself. Their reliability as well as the fact that they remain available when most other vegetation has died certainly seems to indicate the hand of providence.

The most famous (or infamous) product from the seeds is a greasy extract with the stench of the strongest cheese. It typically comes in the form of sticky blackish balls, well known in West Africa, where itinerant traders barter them under the Hausa name dawadawa as well as under the name soumbala (Bambara- and Malinké speaking peoples of central West Africa). This fermented material keeps well even in tropical heat and is rich in protein, vitamins, and food energy. Mostly used as a seasoning, it is also an important soup ingredient.

Outsiders may scoff at dawadawa, but it is no less beloved by its aficionados than is limburger in Europe, fish paste in Indonesia and Vietnam, or Vegemite in Australia. Throughout the northern part of West Africa it is a regular dietary item. In some areas it is eaten at least once a day almost every day of the year.

Thanks to dawadawa, locust seed is a major item of commerce across West Africa. However, producing the pungent paste is a traditional family craft and, although some dried beans are sold in local markets, most are collected and processed by individuals for their own use. Overall, it is estimated that 200,000 tons of locust seeds are collected annually for dawadawa just in northern Nigeria.[1] Making and selling this product constitutes an important economic activity for women.

Because of all this, locusts—along with baobab (Chapter 3) and shea (Chapter 17)—are among the most commercially valuable of all parkland and farm trees in that and other parts of the region. Although they are among the commonest natural trees seen across the park savanna of West Africa, each one is the property of a nearby villager. Those ownership rights are worth hanging on to. As far back as 1964, the seeds from a single locust were valued at around $20 a year.

[1] Campbell-Platt, G. 1980. African locust bean (*Parkia* species) and its west African fermented food product, Dawadawa. *Ecology of Food and Nutrition* 9(2):123-132.

Saboba, northern Ghana. In this savanna region locust bean trees populate a field of the native cereal called fonio. The locust, which has received almost no horticultural recognition, combines likely answers to Africa's twin needs of food and tree cover. Its seeds are gathered by the thousands of tons and peddled by itinerant traders throughout West Africa. Chiefly, they are fermented into the famous dawadawa, a cheesy solid rich in protein, vitamins, and food energy. In some ways it takes the place of cheese or meat in a European diet. It keeps well without refrigeration even in the tropical heat and is popular as a seasoning and soup ingredient. (Yosei Oikawa)

Thus, locusts are sometimes the only trees to be seen in the West African savannas. They are left standing whenever bush is cleared. Indeed, several West African nations have laws against cutting one down. Some chiefs, stressing that the trees are living creatures in need of their protection, demand a fee before permitting the owner to harvest his own beans.

Despite all this monetary, nutritional, and environmental importance the species has seldom been accorded systematic silvicultural development, nor has it been promoted in regions outside its native habitat. Given the powerful possibility of increasing food production, rural development, nutritional well-being, and forest cover with one crop, this seems a shameful neglect.

Perhaps the idea of reforesting swatches of savanna with this food tree is extreme, but it is noteworthy that locust thrives on a wide range of alluvial,

sandy, and lateritic soils and has very low susceptibility to pests and diseases. It survives fires and thrives in full sun and tropical heat. Moreover, it is deep-rooted and almost independent of equable rainfall. According to some accounts, seeds sprout readily, seedlings transplant well, and young plants grow quickly. All this would seem to make locust an ideal candidate for planting in appropriate parts of Africa, especially the long-ago deforested savannas. They also make many shady, edible avenues for now sun-drenched cities, towns and highways.

PROSPECTS

Given its importance to traditional rural populations, this multipurpose legume could certainly be employed more widely and more intensively. The existing trees almost all grew up in the wild; how the species will respond to the hand of horticulture remains uncertain, despite the seeming evidence of the millions of existing specimens. It is encouraging that in recent years several projects have begun to focus specific attention on *Parkia biglobosa* to conserve its germplasm and extend the uses by improvement of agronomic measures.

Within Africa

Clearly prospects are greatest in West Africa, where the plant and its products are known and loved. A major constraint, however, is that the popularity of dawadawa may be diminishing. Possibly, this is because the product’s quality is variable and its shelf life unreliable. Possibly, it is because European dried soups and bouillon cubes are highly promoted on the urban markets in francophone countries). Possibly it is due to the recent appearance of soybean substitutes, fostered through development agencies on the basis that soybeans are easier to grow and process. Quality dawadawa, however, still seems preferred everywhere, and should always have a ready market.

Humid Areas Unknown and unlikely. Possibly locust trees will survive under greater rainfall and humidity than they get in their native habitat; it seems not likely that they will become food crops there.

Dry Areas Here, locust trees are potential sources for food, edible oil, fodder, lumber, firewood, and green manure. Their particular importance is not so much for reforesting the deserts or the Sahel, but the savannas, parklands and agroforestry situations, where plant life is already present but not of great benefit. Trees that yield vital products in drought years could be good not only for people but for the whole area and the creatures in it. However, locust seems more sensitive to drought than many of its other companion species.

Upland Areas Locust seems likely to find a niche in warm upland areas, but that niche may prove too small for investment of targeted resources.

Beyond Africa

The plants are worth testing in tropical savannas worldwide. How they will perform is hard to gauge, but it seems possible that they will complement better-known nitrogen-fixing trees such as leucaena and calliandra by outperforming them in places just a little too dry for them to exert their normal vigor. It seems unlikely that locusts will be employed for food in such locations, but their other benefits to people and the soil are enough to warrant initial trials.

USES

Like so many species in this book, the locust provides a wealth of useful products.

Pulp As noted, the colorful pulp within the pod is eaten raw as a sweetmeat, mixed with water and made into a refreshing drink, used as a sweetener in different foods, and fermented into an alcoholic beverage. It is popular with children. It is also popular with travelers, and keeps so well that it is commonly taken on long journeys.

Seeds In the production of dawadawa the seeds are boiled up to 24 hours, pounded, cleaned, and rendered down into a black paste, which is then set aside to ferment. After two or three days the odoriferous result is pressed into cakes or balls. In the dry form these can keep for over a year in traditional earthenware pots, without refrigeration. Small amounts are crumbled into traditional soups and stews, which are usually eaten with sorghum or millet dumplings and porridges. (The dawadawa is added during the cooking process because the powerful smell then disappears.) Because of its savory taste and high protein and energy values, it is sometimes described as a meat or cheese substitute, but it is often more like a condiment that is eaten in tiny quantities. In parts of Togo, Ghana, Burkina Faso, and Nigeria daily per-capita consumption has been estimated at 4g, 2g, 12g, and 1 to 17g, respectively.[2] The seeds are also sometimes roasted as a coffee eaten in

[2] Ibid.

Dantokpa market, Cotonou, Benin. "Mustard" made from seeds of the savanna tree commonly called locust in English is essential for making nutritious soup. Across West Africa locust bean is a major item of commerce, as is its major processed form, dawadawa, a nutrient-dense, cheese-like food. These together constitute an important economic activity for women. Production of the pungent paste is a traditional family craft and although most is produced for home use, some ends up being sold in local markets. (L.J.G. van der Maesen)

tiny quantities. In parts of Togo, Ghana, Burkina Faso, and Nigeria daily per-capita consumption has been estimated at 4g, 2g, 12g, and 1 to 17g, respectively.[3] The seeds are also sometimes roasted as a coffee substitute, "café de soudan."

Wood The white, yellow, or dull brown wood is soft, medium-grained, and easily worked. It is said to be of less than top quality, but is used for house posts, mortars, bowls, and some carpentry. Most, however, goes for fuel. In the 1970s, it was estimated that locust probably constituted over 90 percent of the firewood supplied to Kano, a Nigerian city whose population was over 250,000 at the time.

Shade The tree makes a superb avenue tree, especially for the drier regions, where shade is perhaps the most precious of all commodities. In thousands of villages it is planted at eating- and meeting places, for shade, for shelter from desert winds, for beautification, and as an insurance against the several times in a generation when it is needed to save lives.

[3] Ibid.

Land-Improvement Not only is this a useful windbreak and shade tree, it is a benefit to the soil. Sites beneath this legume are improved by dung and urine of the livestock sheltering there (attracted by the shade and possibilities of browse). They are also improved by the leaf fall, which is so abundant and so rich in nitrogen and minerals that in certain places the leaves are collected for soil improvement, like manure.

Living Tree Locust is one of the trees that provide poor people a toothbrush. Its twigs are used to brush thousands of teeth a day in countries such as Niger. The bark stains the mouth red but the soapy compounds (saponins) it contains clean teeth. Locust also provides good bee forage. And the fruits and seeds are consumed by a wide variety of animals, including monkeys, making the trees friends of wildlife as well as people and the land.

Forage The sugary pods are much relished by cattle and other domestic livestock. Throughout the region they provide a valuable dry-season ration. The leaves also are traditionally used, whole branches being lopped for fodder. During the dry season, when other feed supplements are scarce or impossible to find, both the ground-up seeds and the sugary pulp are relied on as pig food in northern Nigeria.

Medicinal Uses The bark is an ingredient of ancient remedies sold in Senegalese and other West-African markets or used in the villages. It is also sold for mouthwash, vapor inhalant for toothache,[4] or ear complaints. Many trees in the sub-Sahel zone appear maltreated from harvesting square patches of bark about 15-20 cm square.

Plaster The pod valves can be fermented in water and the resulting liquid is used to decorate walls of loam houses (e.g., in Burkina Faso).

NUTRITION

Although not eaten in quantity, the seeds make a concentrated food containing a nice balance of protein, fat, sugar, starch, and fiber, not to mention vitamins and minerals. About 7 percent of the protein is lysine, a level similar to that in whole egg, one of the best protein foods known. Unfortunately locust seeds are deficient in two other critical amino acids, methionine and tryptophan.

The fat in the beans is nutritionally important. Approximately 60 percent is unsaturated, the major fatty acid being linoleic, a nutritionally useful

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[4] Perhaps it contains acetyl salicylates, a feature that gave rise to aspirin when they were found in willow bark in Europe in the 1800s.

ingredient often missing in poor-people's diets.[5]

The fermented locust-seed product, dawadawa, is equally nutritious. It too is rich in protein. Like the bean itself, it is deficient in certain amino acids, but is rich in lysine. In addition, it contains about 17 percent of a semisolid fat. Further, it contains an array of vitamins, notably vitamin B2.

The floury pulp surrounding the seeds in the pod, sometimes called dozim, is an energy-packed food with up to 60 percent sugar. It is also high in vitamin C (291 mg per 100g dry matter in one analysis[6]). This is yet another locust food that becomes available in the season when little else is available for the picking.

HORTICULTURE

Although there are no known major plantings, methods for producing the plants in nurseries have been elaborated.[7] The trees can be propagated by seed, which grow rather vigorously. An overnight soak in hot water has been suggested as a pretreatment.

Vegetative propagation is also possible, but apparently is difficult. Trial plots of grafted locust have been established by CNSF in Burkina Faso. The tree also has been propagated by budding, to produce early fruiting, in Nigeria.[8] Pruning of seeding trees is said to hasten fruiting.

HARVESTING AND HANDLING

Pods are picked from the tree, sometimes by climbing but more often by using a long pole fitted with a knife at the end. Transporting these flat leathery pods presents few problems. Most are hauled around roughly in baskets or sacks.

LIMITATIONS

Just how good a return any planter will get is mere guesswork. The seed yield is reported to be low (between 350 and 500 kg per hectare), a feature to be expected in a wild plant and one that would likely improve dramatically in managed plantations.

The seeds have tough leathery seedcoats; they have to be cooked or peeled before eating. Even more than for some other pulses, cooking times for the toughest beans can extend out twelve hours or more, consuming large amounts of precious fuel.

Though no part of the fruit contains cyanogenic glycosides, the raw seeds

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[5] Odunfa, S.A. and A Adesomoju. 1986. Fatty acid composition of African locust bean (*Parkia biglobosa*). *Chemie Mikrobiologie Technologie Lebensmittel* 10:125-127.

[6] Campbell -Platt, op. cit.

[7] For example, by the Forest Seed Centre of Burkina Faso.

[8] Information from J.C. Okafor.

are suspected of containing anti-nutritional factors. Those must be eliminated in the cooking process. It is reported, for example, that in cooked locust seeds the only factors that lower nutritive value are the low levels of methionine and tryptophan. This was deduced from the fact that diets supplemented with those amino acids increased the growth of rats to almost that obtained with whole egg.

Although the mature tree is a fire-resistant heliophyte that needs little protection or care, the seedlings are harmed by browsing and hence need careful safekeeping from wandering livestock.

General distribution of locust bean. It is noteworthy that the tree thrives on a wide range of alluvial, sandy, and lateritic soils. It also resists pests and diseases, resists fires, and thrives in full sun and tropical heat. Moreover, its deep-roots make it almost independent of equable rainfall. All this would seem to make locust an ideal candidate for mass planting in appropriate parts of Africa, notably the once-forested savannas. (M.R. Dafforn, after Frost Entomological Museum, Pennsylvania State University and other sources)

NEXT STEPS

To turn locust into a reliable food resource, there are many steps that could be taken and a few that must be taken. Both are mentioned here.

Plantings Ideally, a major initiative could be mass planting of locusts wherever they can take root and thrive. Also, fostering village plantings can be recommended. At that time a key barrier will be the availability of sufficient top-quality seed. Given high expectations, it would not be amiss to establish seed plantations in preparation for the day of mass demand. As an agroforestry species, it can be highly recommended—no delay for further research or trials seems necessary. Perhaps its greatest promise will occur on lateritic sites. The growth is stunted but under such circumstances growth rate is far less important than survival. These red, acid, aluminous, mostly barren soils beset the tropics, and are one of their main causes for low productivity and hunger.

Locust would appear to be a superb multipurpose agroforestry species. Many areas have lost much of their tree cover, and farmers have begun to reestablish specific beneficial species, including locust. The promotion of maintenance, strengthening and reestablishment of such agroforestry associations would seem to hold the best prospects for the tree in local livelihood systems. Possibly, locust could be planted in association with

Labé, Guinea. Farmer shelling locust beans. Although a regular part of the diet, the beans become lifesavers during times of famine. The seeds contain protein, fat, sugar, starch, fiber, vitamins, and minerals, and are a concentrated and very balanced food. Add the fact that they mature in the dry season, the traditional "hungry time," and their value as emergency rations becomes plain. Even when drought has seared the landscape, this deep-rooted tree continues producing food almost as if independent of the weather. (IFAD/Roberto Faidutti)

shea and the occasional baobab.

Small cooperatively managed plantations, especially those owned and managed by women, might be a real boost in some places. On the other hand, investment in larger-scale plantations by business people and civil servants from the city might destroy entirely the cottage industry based around the production and sale of dawadawa, which comprises a significant portion of women's, albeit meager, incomes across the region.

Horticultural Improvement Because there have been few conscious attempts at yield improvement there is probably much potential to select for improved yields. Many approaches seem promising. For one, research into pests and diseases, plant nutrition, and cultivation techniques may lead to vast improvements. For another, plant physiological research may indicate ways to encourage a larger number of hermaphrodite flowers to develop into pods. Some evidence suggests that trees in plantations perform better than isolated trees, and improvement of plantation establishment techniques could contribute substantially to production.

Genetic Selection A selection of superior strains is certainly needed.

Throughout West Africa there are many varieties with different forms, seed sizes, seed colors, and so forth. Ample germplasm exists for selection and breeding work. Thus, there is much scope for selection and building up extremely productive plantations by choosing superior specimens. Establishment of provenances, documentation of genetic variation, selection for improved cultivars, (e.g., precocity in fruiting) is also needed. In sum, this species is like a recently opened book, just waiting to be read by more locust lovers, students, plant scientists, and nurserymen.

Vegetative Propagation As stated, both grafting and budding have been conducted successfully. “Plus trees” could be selected as the basis for seed orchard establishment, with tree planting campaigns promoting locust bean trees using budded seedlings.

Management Pruning trials should also be carried out with the existing seedling trees, with active participation of local farmers. It is said that pruning speeds fruiting.

Pollinators Wind, bees, and flies all contribute to pollination, but it is also reported that bats can be major pollinators of locust trees. Encouraging bat populations in plantations could be very helpful for increasing seed.

Food Technology There is a need for research into the presence of alkaloids in the seeds. These are possibly confined to the seedcoat (testa), which is usually removed before the seed is used as food.

Additionally, the whole process of commercial dawadawa production needs modernization research.[9] Such things as defined starter cultures and standardized (and sterile) processing might provide more consistent flavor, improve shelf life, and help maintain its overall popularity. Also, processing methods that reduce the smell might be developed, so dawadawa can better compete with soybean substitutes and bouillon cubes in the commercial markets. Moreover, technologies that require less labor and fuelwood would truly help the producers.

Sustainable Agriculture

There is the possibility of creating continuous cropping systems around locust. Deep-rooted trees such as this could be a key in semi-arid areas. The short rainy season is the limiting factor to farming, if not life, and therefore the cropping systems in these areas have to be designed on the basis of the water availability.

[9] Achi, O.K. 2005. Traditional fermented protein condiments in Nigeria. *African Journal of Biotechnology* 4(13):1612-1621; online at academicjournals.org/AJB.

SPECIES INFORMATION

Botanical Name *Parkia biglobosa* (Jacq.) R.Br. ex G.Don

Major Synonyms *Parkia africana* R.Br., *Parkia intermedia* Oliver, *Parkia clappertoniana* Keay.

Family Leguminosae. Subfamily: Mimosoideae.

Common Names

Bambara: néré
English: African locust bean,
French: arbre a farine, arbre a fauve
Nigeria: nitta, nete, nere, dawa-dawa, dawadawa, dadawa, ogiri okpi (Igbo)
Fulani: narghi
Gambia: monkey cutlass, netetou
Sierra Leone: kinds
Sudan: dours
Chad Arabic: maito
Kanouri: runo
Djerma: dosso
More: rouaga

Description

African locust trees are large in size: typically over 18 m high and 1.5 m in trunk diameter. They are considered handsome, with clear, rough-textured trunks, fine feathery bipinnate leaves made up of many leaflets, and red, club-shaped flower heads about 5 cm in diameter. The pods are 15-42 cm long and 2 cm wide, and appear in long hanging clusters. The trees lose their leaves during the dry season. Indeed, they are often wholly or partially leafless whilst flowering.

The flowers begin to open at dusk, close and wilt at dawn, lasting only a single night. They are reportedly hermaphrodite. However, the topmost flowers in each cluster are said to be sterile, and produce copious amounts of nectar, presumably to attract fruit bats. While open, the flower clusters resemble pom-poms, an ideal structure for bat pollination. Bees also frequent the flowers in the early hours of the day, and are certainly important pollinators.

Distribution

Locust is not strictly a Sahelian species. It is more properly a savanna species, common also in deciduous forests. In Senegal it extends to the northern limit of the Sudanian Region; further east it is less widely distributed in the drier northern parts, but reaches the southern boundary of the Sahel in Nigeria and Niger.

Within Africa Senegal, Gambia, Mali, Guinea-Bissau, Guinea, Sierra Leone, Côte d'Ivoire, Burkina Faso, Ghana, Togo, Benin, Niger, Nigeria, Cameroon, Chad, Central African Republic, Sao Tome, Gabon, Democratic Republic of Congo, Sudan, Uganda.

Beyond Africa African locust is found on several Caribbean Islands. It is naturalized in Haiti, for instance. Possibly, this is a holdover from the slave trade, and the African love of locust.

Horticultural Varieties

No formal varieties exist. There are considerable genotypic differences, often well known to locals, that are proving useful in making formal selections.

Environmental Requirements

Rainfall The species has been observed growing where mean annual rainfall is 400 mm, but it usually occurs where rainfall is 600-700 mm. It has also been recorded where rainfall is 1200 mm.

Altitude The limits are unknown, but altitude is probably not a practical limitation, at least in equatorial latitudes.

Low Temperature Freezing weather is foreign to its native habitat, but the plant is certainly frost sensitive.

High Temperature Locust trees thrive in semiarid tropical climates with an average daily maximum above 33.5 °C.

Soil It is adapted to a wide range of alluvial soils and is known to grow on shallow drift sands as well as on deep, heavy sand (the type on which sorghum grows well). It does best, however, on deep, cultivated soils but occurs on shallow skeletal soils and is known to survive on poor, rocky sites. In technical terms, it has been said that the sites suiting locust are those with tropical ferruginous soils, ferrisols, and moderately leached ferralitics.

Related Species

Parkia filicoidea. is a related African species from riparian forests. Other species occur both in tropical Asia and Latin America. These are generally handsome, quick-growing trees, large in size, with clear, smooth trunks and fine feathery leaves. They too are useful and highly regarded. Most are pollinated by bats as well as bees. Examples include:

- *Parkia speciosa*. Indigenous to Southeast Asia, where it can be found in cultivated plantations. There the odorous/stinking seeds are eaten raw. roasted and fried after sun drying and storage, or else cooked in sauces and curries, more as a condiment. In Indonesia and Malaysia, the pods are an important foodstuff. When ground into a meal, they make a nutritious ingredient of livestock rations. These trees may be found in fairly moist areas in southern Asia. Many of the species are noted for the pods or beans and nuts they bear, which are of good quality and make excellent and nutritious foodstuffs. The leaves also provide useful forage for livestock.
- *Parkia biglandulosa*. Malaysia. Seeds roasted, also a substitute for coffee; seedlings also consumed.
- *Parkia intermedia*. Indonesia. Seeds eaten raw or roasted.
- *Parkia javanica*. Indonesia, Philippines. Pods used for flavoring.
- *Parkia roxburghii*. Thrives in moist low areas up to about 600 meters above sea level.

These further members of the genus *Parkia* are worthy of much more extensive planting, with progressive breeding and selections of improved strains. Several institutions in various parts of Asia and the Americas have begun showing an interest in developing them for forestry and farms.

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LONG BEAN

In Asia there is a special vegetable, renown by growers for its productivity, by chefs for its appearance, and by diners for its flavor and tender-crisp texture. Reportedly, it is one of Southeast Asia's top ten vegetables, grown especially in southern China and Taiwan. That report, however, does it less than justice. In addition, it is the most widely grown legume of the Philippines, where it is known as "poor-man's meat." It also is very well known in Indonesia, Thailand, Vietnam, Bangladesh, India, and more.

In recent decades, this popular bean has begun picking up aficionados far beyond Asia. Indeed, there is now a rising regard for it worldwide. Many countries already consider it a leading Oriental vegetable. In Europe, for instance, it is being grown extensively. And the United States has also begun producing it on a large scale for Chinese, Thai, Filipino, Vietnamese, and Indian restaurants. It is now found year-round in America's Asian markets and in those supermarkets that have specialty produce sections. Yet the demand keeps rising. California growers, for example, can't seem to produce enough; importers bring in additional supplies from Mexico and the Caribbean to meet the needs of places such as Los Angeles and San Francisco.

This special foodstuff is the pod of an unusual legume. It resembles a snap bean except for one singular fact: it is pencil-thin and as much as a meter long. Often called yardlong bean in English, these green to pale-green pods are tender, stringless, succulent, and sweet. Typically, they are sliced and boiled and served with a little butter, like string beans. Their crisp texture and flavor hold up well when steamed or stir-fried. Most enthusiasts claim they resemble French beans. Some detect a mushroom-like taste. A few note in them a hint of asparagus, a connection reflected in this plant's other common name, "asparagus bean." All agree, however, that it is delicious.

A surprising thing about this "Oriental" vegetable is that it is not from the East at all. In the beginning—thousands of years ago—it was unknown to any Asian, or for that matter any European or New World inhabitant. But it was well known to Africans. This historical fact is a fairly new realization. A century ago even botanists were fooled into labeling the plant *Vigna sinensis* (bean of China). But now we know that it is nothing more than a

This delightful vegetable resembles a snap bean except for the singular fact that it is pencil-thin and up to a meter long. Often called yardlong bean in English, its green to pale-green pods are tender, stringless, succulent, and sweet. A surprising thing about this universally acclaimed "Oriental vegetable" is that it is a very special form of cowpea—a plant of unquestioned African origin (see Chapter 5). Now is the time to welcome long bean back home and put it to work in Africa. (East West Seeds International)

very special form of cowpea, *Vigna unguiculata*—a plant that unquestionably arose out of tropical Africa thousands of years ago (see Chapter 5).

This ancient African, which has blossomed to become a modern Queen of Asian Cuisine, is an oddly shaped vegetable, so long as to seem grossly out of proportion. No wonder some people call it snake bean. The strange thing is that this snap-cowpea's main evolution happened after it left home, so the long, long, long pod is hardly known in the lands that gave the species birth.

Now is the time to welcome back this child of Africa, and to put it to work as in the rest of the world. Indeed, in principle at least, this wanderer from the local genepool should be in virtually every African village. It lends itself to poor people's needs and conditions. It is productive, yielding a lot of food in a very small space. On worn-out soils it is said to outyield peanuts. A true legume, it is largely independent of fertilizer….enriching soil by trapping atmospheric nitrogen in nodules on its roots. It is not only tasty; it fits into African cuisine, especially the vegetable-laden sauces and relishes.

Long beans thrive in hot humid climates, and produce food very quickly.

Indeed, the succulent leaves can be harvested as soon as 21 days after planting, and some types produce harvestable pods within 60 days. The main varieties continue producing over long periods of time, thus giving rise to an extended harvest that keeps providing fresh pods for months.

That harvest is salable, profitable and, above all, nutritious. Not for nothing do Filipinos call it poor-man's meat. Both seeds and tender leaves contain 25 percent protein, of high nutritional quality. The US National Aeronautics and Space Administration is so impressed with this plant's nutritional potential it is considering growing it in space to feed astronauts.

PROSPECTS

There are bright prospects for long bean in the African diet.

Within Africa

Already in certain parts of Africa cowpea pods are eaten. For this reason, the extra-long, highly developed versions now livening cuisines and brightening dinner plates from New Delhi to New Orleans won't arrive as a foreign food. They are meatier, sweeter, and a paler shade of green than are Africa's current type. Thus, these foreign counterparts should take on quickly when people find how tasty and tender and attractive they are.

Humid Areas Excellent.

Dry Areas Good. Cowpeas are especially important in regions that are a little too hot and a little too dry for beans and peanuts. Although for top production and pod quality they need water, this is not so difficult to provide in an intensively produced backyard crop. Long bean, however, may be less drought tolerant than cowpea even though it is the same species.

Upland Areas Good. Long beans are said to produce poorly at elevation in the tropics. Nonetheless, there are many pockets where temperatures will prove conducive to this fast-maturing annual.

Beyond Africa

Although the long bean is far better known outside its African homelands, it still has untapped potential in Asia, Europe, and the Americas. Yet that potential is likely to be exploited without too much help from public science.

USES

This is another multipurpose plant.

Pods The pods are picked when they are still smooth and immature, before the seeds swell. They are eaten fresh, frozen, or canned. At this young and tender stage, they can be prepared in various ways. Most are sliced and sautéed or stir-fried. Recent suggestions by a cookery consultant include the following: stewed with tomato sauce; boiled and drained, then seasoned with lemon juice and oil; or simmered in butter or oil and garlic. Overcooking is to be avoided: it turns them mushy.

Shoots In many parts of the tropics the young stem tips are steamed or boiled and eaten like asparagus.

Leaves In many areas the leaves of long bean (as well as of cowpea) are also regularly consumed. To make a good spinach the leaves must be young and tender.[1] Although they are usually simply boiled and eaten, some are crushed, fried, and boiled. Also, some cowpea leaves are dried and ground into a powder that is stored for use during the time of year when fresh vegetables are scarce. In some areas, the mature leaves are boiled about 15 minutes, drained, dried in the sun, and stored for use as a relish. The rapid boiling (blanching) improves the storage and quality.

Experiments in Uganda and Tanzania have shown that removing all the tender leaves three times at weekly intervals, starting five or seven weeks after sowing, has no adverse effect on cowpea seed yields (although it may delay flowering). Thus, even the growers of the grain type can benefit from these cowpea greens.

Other Uses Long beans can also be used as fodder. In India and some other countries, cowpea is grown as a dual purpose crop: the green pods are harvested for use as a vegetable and the residual plant material, containing about 12 percent protein on a dry matter basis, is used for feeding livestock.

NUTRITION

Long bean pods provide only about 50 calories per 100 g when cooked, and are low in protein (>3 percent[2]). They also provide modest vitamin C (about 15 mg) and provitamin A (23 µg RAE), but have good levels of folate (about 45 µg), so critical for growing new cells during pregnancy and infancy. As noted, the tender leaves of the plant are nutritious as well. These contain 25 percent protein as a percentage of dry weight, and the protein is of high quality.

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[1] One commentator claims that the best leaves are “the third and fourth from the apical ends of the shoots.”

[2] Mature seed, sometimes eaten in Asia instead of the immature pods, contain about 25 percent protein when dry.

This productive legume yields a lot of food in a very small space. On worn-out soils it is said to out-produce peanuts. A true legume, it is largely independent of fertilizer—enriching soil by trapping atmospheric nitrogen in nodules on its roots. It not only fits into African farming it fits into African cuisine, especially into the vegetable-laden sauces and relishes. These tasty, universally admired treats therefore hold out the prospect of a good income for those who choose to grow them for profit. (East West Seeds International)

HORTICULTURE

Long bean is a vigorous annual that is propagated by seed. Its long, trailing growth requires a trellis or pole for best production. The plant will climb by itself, but still needs some help and a very strong trellis system. Poles are also satisfactory, especially if slanted. Training the vine is said to be no more difficult than training a tomato or pea plant.

Typically, the seeds are planted in rows beside a trellis or in hills beside a pole. In the latter case, it has been recommended that 5-6 seeds be planted together for each pole, and then thinned to leave 3 seedlings.

The plant begins producing marketable pods 60 days after sowing. At that stage the pods, hanging in pairs, range from 35 to 60 cm in length. Each pod forms rapidly, growing to marketable length in just 9 days after the flower opens.

The plant thrives in average garden soil that is loose and friable. Soil that is too rich in nitrogen fosters leaf growth over pod production. Since these are legumes, some growers inoculate the seed with nitrogen-fixing bacteria as an alternative to using nitrogen fertilizer. Long bean uses the cowpea (EL strain) rhizobium, which means that it will grow well wherever cowpea does. Thus, in most of Africa no inoculation should be needed. Elsewhere, and especially on barren soils, commercial cowpea inoculum is readily available.

The fact that this versatile crop is a form of cowpea (blackeye pea to Americans) is clear if the plant is let go to seed. In parts of China, long bean is allowed to mature a crop of seeds at the end of the season.

HARVESTING AND HANDLING

The pods keep coming throughout summer and into the fall, and have to be harvested frequently (weekly, if not daily). If they are left unharvested the plants stop producing. They are usually picked when about half the diameter of a pencil, before the seeds have filled out inside, and when they still snap when bent. If that stage is missed, the seeds swell and the pod itself turns tough and inedible.

Yields depend on the site and the grower, but in a field test at Riverside, California researchers measured marketable yields of up to 11,100 kg per hectare with three different cultivars of bush long beans.[3]

The pods are best when eaten soon after harvesting but they can also be blanched and frozen for storage. If refrigerated, they keep in a plastic bag for up to 5 days. US Department of Agriculture recommendations for commercial dealers are to store them at 4°-7°C and 90-95 percent relative humidity, which provides a storage life of 7 to 10 days.

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[3] Apparently, the testers quit counting while the plant was still bearing more pods. "Based upon the plants and their fruiting condition at the end of the harvest as well as the indeterminate nature of the crop," they said, "the potential yield was probably greater."

Marketing long beans is usually not too difficult. However, they must be picked exactly on time and handled with care. As one review noted: "It is easy to make them look bad…old, dry beans look terrible." The reviewer recommended choosing "slender, crisp, blemish-free beans" and warned that harvested pods quickly develop "rusty patches."

LIMITATIONS

As with common beans, it is recommended to rotate the planting locations every year and not plant at the same spot within 3-4 years.

In different locations different pests are likely to be encountered. Root-knot nematodes (*Meloidogyne* sp.) cause severe problems on cowpea in many areas of the world, including the US. Nematode resistance varieties are the best and most economical solution to this problem. In California the following warning has been given: "Aphids, particularly the cowpea aphid (*Aphis craccivora*), are drawn to the pods, leaves and stems. Planting the crop near others infested with this aphid, is 'asking for trouble.' Thrips tend to be a pest early in the season if temperatures are cool, but the plants will often outgrow them, especially as the weather gets warmer and the plants grow faster. Mites can be a problem, primarily after insecticide applications, which often lead to mite outbreaks." Lygus bug (*Lygus Hesperus*) attacks the young floral buds and developing pods of blackeye cowpeas so if potentially a severe problem on long bean as well. In the southeastern United States, cowpea curculio and pod sucking bugs (including the green stink bug *Nezara viridula*) are major pests of cowpea and will attack long bean as well.

It seems logical to assume that long beans are susceptible to all cowpea diseases. Indeed, the same report from Califonia noted that, "they are damaged by fungi causing rust and mildew as well as by cowpea aphid-borne mosaic virus and cowpea witches' broom virus. Virus control is aided by destroying infected plant materials and controlling aphids, whiteflies, leafhoppers and beetles that carry the virus from plant to plant. [Long beans] often are relatively pest-free compared to green bean varieties; however, the bean shoot fly and the bean pod fly may hamper growth and pod production. Remove and burn damaged plant materials to prevent spread of pest species."

NEXT STEPS

Because of global experience with long bean, African nations could mount programs right now to foster its adoption and better use. Anyone involved in vegetable production in Africa could get involved. A continent-wide program to advance and nurture long bean could take advantage of the varying experiences among countries. The best seeds and knowledge exist in Asia, so there could also be an intercontinental swap of germplasm and

expertise. Many varieties unknown in Africa are available, generally identified by the color of mature seed. Examples include the purple-hulled, pink-eyed, dark-brown seeded, white-seeded, and speckle-seeded. There are also purple-podded and knuckle-podded varieties. Asian countries could do much by transferring seeds and horticultural know-how, and could possibly receive much in return from the biodiversity of long bean's ancestral home.

As noted, cowpea pods have been traditionally eaten in some areas of Africa. Even now, these, together with the plant's fresh green leaves, are exceptionally important because they are among the earliest foods available at the end of the "hungry time." Together with long bean, these are equally deserving of support and improved use.

Africans are not used to eating green cowpea pods as a green vegetable, but rather they prefer dry cowpea grain. They need to know that long bean is better consumed as green tender pod, for seed of long bean is lighter than cowpea, and so are not as productive when seed is used compared to green pods.

Food Technology This "new," elongated cowpea pod should be checked in various African dishes. This would likely turn up many a potential market success. Frozen vegetable processors should try long bean in mixed packages of frozen vegetables.

Horticultural Development The newer bush varieties in Asia also deserve consideration. They have the same meter-long pods but require no trellis or pole and thus are easier to manage. In the Philippines, Bush Sitao (a cross between long bean and common cowpea) reportedly is replacing the viney form in the favor of farmers. It is bush-shaped, needs no trellis, and is less susceptible to wind damage than long bean.

The International Institute of Tropical Agriculture in Nigeria has developed several lines of vegetable cowpea that resemble long bean in some respect (tender pods). The lines were actually developed from the Philippine "bush sitao." Most are determinate plant type.

There is a concern of heavy pesticide use in long bean in Southeast Asian countries. This is an area where research is needed to find ways to produce this crop using reduced or minimum pesticides.

SPECIES INFORMATION

Botanical Name *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc.

Synonyms *Vigna sinensis* subsp. *sesquipedalis* (L.) Van Eselt.; *Vigna sesquipedalis* (L.) Fruwirth

Family Leguminosae. Subfamily: Papilionoideae (Faboideae)—Pea family

Common Names

English: yardlong bean, asparagus bean, bodi bean, snake bean, Chinese long bean
French: dolique asperge, dolique géante, haricot kilomètre, haricot asperge
Portuguese : feijão-chicote, feijão-espargo, dólico gigante.
China: dow gauk, dou jiao, chang qing dou jiao, chèuhng chèng dauh gok (Cantonese), ch'eung ts'ing tau kok (Cantonese)
Philippines: sitaw, sitao (Tagalog), hamtak, banor (Visayan), balatong (Ilongo)
Indonesia: kacang belut, kacang tolo
Malaysia: kacang panjang, kachang panjang
Thailand: Tua fak yaow, Tua phnom.
Hmong: taao-hla-chao
Japan: juro-kusasagemae, sasage, juuroku sasage
Vietnam: dau-dau, dâu dûa, dâu giai áo

Description

This is a pole-type bean, growing 3 to 4 m high. The flowers, which are conspicuous and apparently self-pollinated, are borne on short pedicels and may be white, pale-blue, pink, or violet. They commonly open early in the day and close around midday, only to wilt and collapse. The pods can vary greatly in size, shape, color, and texture. They may be linear, curved, or coiled, and normally vary from 8 to 45 cm in length, but can reach 100 cm. They are indehiscent, usually pale green or yellow when ripe, although brown or purple-colored ones can occur. They normally contain 8-20 seeds, which also vary in size, shape, and color. The commonest, however, are white, creamy-white, or black.

These thin, soft beans may grow on delicate stems but they are supported by a tenacious root system. The plant is indeterminate, meaning it continues to grow after flowering and fruiting.

Distribution

Within Africa On the basis of modern evidence, there is no doubt that the cultivated cowpea originated in central Africa from where it spread in early times through Egypt or Arabia to Asia and the Mediterranean. Fifty years ago the British botanist, Burkill, stated that the cowpea reached Sumeria about 2300 B.C. Perhaps that was the first leg of its journey away from Africa. In its new home across the seas, this wandering scion of cowpea took on the new guise of a long, long bean and began masquerading as an Asian food.

Beyond Africa Long bean has been introduced to many lowland tropical countries where often it is a garden vegetable. The plant was taken to the West Indies in the 1500s and reached today's United States in about 1700. It is popular in the Caribbean and is grown as a summer crop in California, and has become increasingly popular with home-gardeners in the United States. In parts of Europe it is grown especially as a greenhouse vegetable. The crop is produced most widely in the Far East. China and India are both modern centers of long-bean diversity, but unique varieties are to be found in most Southeast Asian nations.

Horticultural Varieties

Dozens, scores, probably hundreds of different types are featured in catalogs of seed companies in worldwide. These are worth trying, although many will differ only in color and other cosmetic features. Varieties from the tropics may be photoperiod sensitive and will not flower under the longer days of summertime in temperate or even subtropical regions.

Environmental Requirements

This warm-season crop can be planted in a wide range of climatic conditions, but is sensitive to temperature and grows relatively slow in mild or cold environments.

Rainfall Long beans easily tolerate drought but the pods shrink and turn fibrous when starved of moisture. All in all, the long-podded varieties require more water than cowpeas grown for seed. Annual rainfall up to 1,500 mm has been recommended.

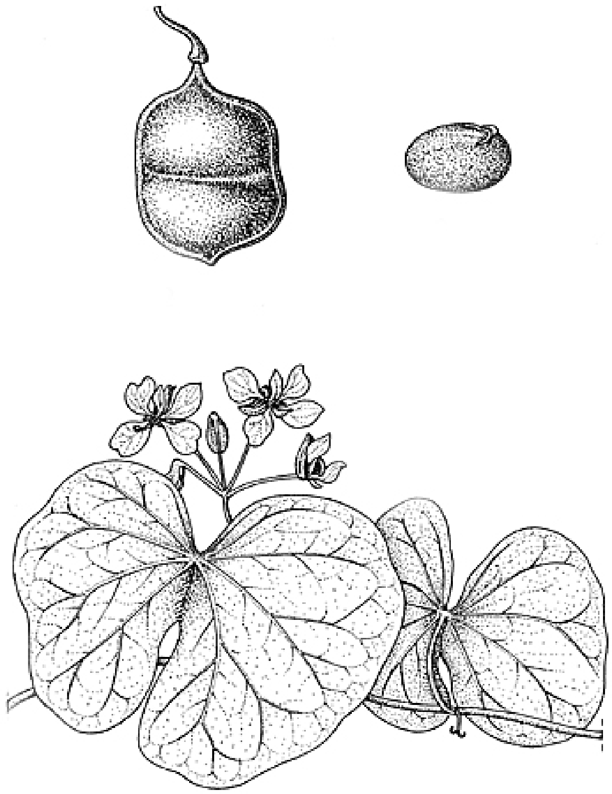
Altitude Despite claims to the contrary, elevation seems unlikely to limit this crop.

Low Temperature Long beans virtually cease growing when daily maximum temperatures are below 20°C. They must be sown after all danger of frost has passed, and to germinate well the soil should be 20-22°C,

otherwise the seeds tend to rot.

High Temperature Long beans prefer high temperature, conditions under which other green beans cannot be produced. Environments with full sunlight attaining daytime temperatures of 25-35° C with nighttime temperatures that stay above 15° C are preferred.

Soil This plant thrives in average garden soil. The plant is a true legume with nitrogen-fixing symbiosis; soil with already too much nitrogen favors leaf growth over pods.



Drawing courtesy of PROTA (prota.org); redrawn and adapted by Achmad Satiri Nurhaman

13

MARAMA

Strange that marama has not been introduced into cultivation. Above ground, this plant produces seeds that rival peanut and soybean in composition and nutritive value. Below, it produces a high-protein tuber much bigger and more nutritious than any potato, yam, or even sugar beet. And the plant also yields top-quality vegetable oil. In addition, it thrives in poor-quality soil and under the harshest of climates. Indeed, in its native habitat droughts often last years on end, a feature ruinous to mainstream crops and most living creatures but not to marama.

Moreover, the life-giving propensities of this resilient species are by no means restricted to food. The plant probably survives the seemingly interminable droughts by drawing on water stored in its tuber, which in dry years shrinks dramatically. Some of those tubers hold an immense amount of water. One dug up in Botswana weighed 277 kg, perhaps 250 kg of which would have been water. In arid and semiarid regions these "living cisterns" become important emergency sources of water for both humans and animals.

Despite these surprising qualities, though, little is known about the plant and almost nothing is understood about its cultivation. Among Africa's many native foods, this remains one of the most neglected. Yet, the record clearly shows that a dedicated research and development effort might well lift this wild species out of obscurity and perhaps project it far enough to contribute importantly to the food supply in some of the most challenging of all agricultural locations.

Marama is endemic to southern Africa. Native to the Kalahari and neighboring sandy lands, it has a long history as a resource. Indeed, humankind is believed to have originated in this general area; marama may have been in our diet as long as any food in existence. Even today it is an important dietary component for some in the region. People in remote settlements and among nomadic groups rely on it as did our earliest ancestors. It is, for instance, a popular delicacy of the Herero, Tswana, and other Bantu-speaking peoples and is a key part of the diet of some Khoisan peoples (!Kung and Khoi-khoi). For some !Kung only mongongo nut surpasses it in importance as a life-sustaining foodstuff.

For all that, the plant has never been regularly cultivated. This is what is so strange. Marama is a rich source of protein and energy, and nourishes

Marama is a wild plant of the southern African deserts. A source of concentrated protein and energy, it nourishes people in regions where rainfall is so slight and erratic that in some years almost no moisture falls whatever. The plant withstands blistering temperatures with ease. It thrives in poor-quality soil. But it remains undomesticated and before anyone can truly capitalize on its amazing qualities a wealth of horticultural development is needed. (Lorna K. Marshall)

people in desert regions where rainfall is so slight and erratic that in some years there is almost no precipitation whatever. The plant withstands blistering summer temperatures apparently with ease. In addition, it survives low winter temperatures, especially the freezing nights of the Kalahari. And yet it is not being raised under the kind of controlled conditions that could bring out its best.

This neglect is not due to scarcity. Within the Kalahari region this is not a rare plant. In some areas of Botswana and Namibia, marama occurs in stands several kilometers across. It is found to a lesser extent in South Africa (northern Cape Province and Gauteng). The typical habitat is an undulating grassveld (savanna), with marama sprouting among the native grass and acacia-thorn scrub on sandy vlies.

It is not due to an unpleasant taste. After roasting the seeds take on a nutty flavor that has been compared with roasted cashew nuts. Europeans in southern Africa have ground the roasted seeds and used them as a culinary substitute for almonds. Africans often boil them with cornmeal or grind or pound them into a powder that is boiled in water to produce either a cocoa-like beverage or a porridge. In taste, then, marama ranks with the best.

Nor is it due to the impossibility of producing the plant in an organized manner. Although no concerted effort at domestication has been undertaken,

it was reported in the early 1960s that, for 20 years, farmers near Barberspan (Western Gauteng) had encouraged the plant by sowing its seeds in spring (October) directly into sand without any preliminary plowing. Following the mention of marama in an earlier book from this office,[1] trials were reported in several parts of the United States in projects located in Texas, Florida, and California, and the plant grew satisfactorily.

PROSPECTS

Despite the fact marama is still a wild plant with vast uncertainties to answer before it can cultivated on any scale, marama seems to have notable prospects solely on the basis of its nutritional composition. By that measure it ranks with soybean and peanut, the two most commercially important legumes, each grown on millions of hectares worldwide. Add to that its rugged constitution and ability to grow where other food crops cannot and the conclusion would seem that this is definitely a plant with prospects.

Within Africa

At first sight there doesn't seem to be much doubt about this plant's potential within its home range. On its web page, one South African university refers to marama as "a versatile legume and potentially high-protein, sustainable food crop for Africa." It also calls it the "magic marama bean, the green gold of Africa." But everyone should realize that there's many a challenge to be overcome before its promise is realized even in the lowest degree.

Humid Areas Although this is an extremely interesting species for any plant lover to work with, its prospects as a useful crop in the humid tropics do not seem high. Better-known tubers and leguminous seed crops—cassava, yam, peanut, and bambara bean, for example—are immediately available for this climatic zone.

Dry Areas Given its extreme drought tolerance, the marama offers the possibility of a new crop highly suited to the compelling needs of semiarid lands. In principle at least it should be tested in projects aimed at alleviating rural poverty and malnutrition in the drought-prone sandy zone of southern Africa.

Upland Areas The prospects here are unknown and uncertain. Any but the most preliminary tests are probably best left until more is learned about the plant and its wider prospects.

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[1] *Tropical Legumes; Resources for the Future*, 1979.

Beyond Africa

Marama will certainly grow beyond Africa. As noted, researchers in places such as the United States, Australia, and elsewhere have trialed it. But in such places it is likely to remain a marketplace curiosity, given the high performance of peanuts, soybeans, and similar crops.

USES

Like many of the species in this report, this plant has a surprising number of practical uses.

Seeds When taken straight from the freshly picked pod the seeds are soft and white and virtually inedible, being nearly tasteless and having an unpleasant, oily texture. Later, they harden, turn brown and become more appealing. They can then be eaten raw but most are first roasted, after which they have a delicious nutty flavor that has been compared to roasted cashew nuts. In this form they are very much liked by groups throughout the region. They are also often boiled with cornmeal, or pounded, mixed with hot water, and made into a delicious soup.

Oil Conventional presses or solvent extraction methods produce a clear and golden-yellow oil from the seeds. It has a pleasant nutty odor and agreeable taste, is similar to almond oil in consistency and appearance, and appears suitable for use in cooking and foods. It is a polyunsaturated oil and seems a good source of linoleic acid, one of the nutritionally essential fatty acids. The meal remaining after oil extraction has a remarkable 52-percent protein content, which could give it a place in local foods or feeds.

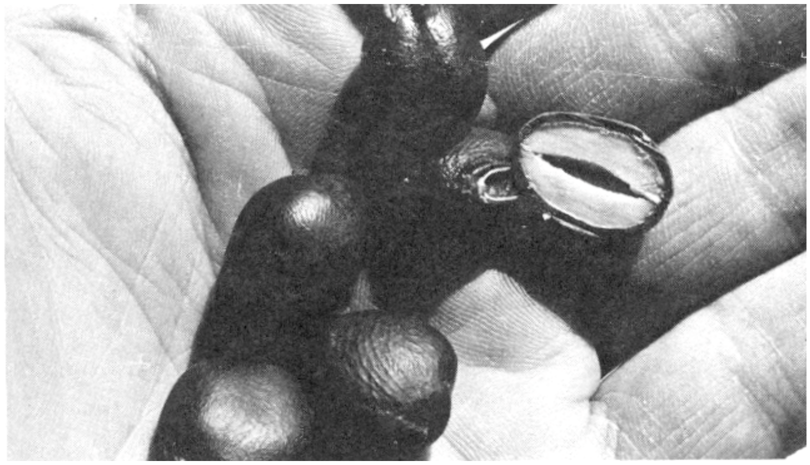
Tubers The succulent red-brown tuber, shaped like a giant top waiting to be spun, can attain enormous weights, as attested by the one in Botswana that achieved almost 300 kg. Normally, inhabitants of the Kalahari dig up young tubers when they weigh about 1 kg. Baked, boiled, or roasted whole, these have a sweet, pleasant flavor and make a good vegetable dish.

Feeds This plant is eaten by both people and animals. Livestock savor the beans, which are said to be especially good for fattening pigs.

Other Uses Wildlife relies on the plants for food and water. Because the gemsbok (a large antelope) eat the seeds and tubers with great relish, the plant is often called gemsbok bean.

NUTRITION

The marama bean analyses made so far have reported record protein contents of 30, 34, and 39 percent. Thus, the marama seed has a protein



Above ground, marama produces tasty seeds that rival peanut and soybean in nutritive quality. (B. Maguire)

content that rivals that of soybean (37-39 percent). Like most legume proteins, marama-protein is rich in lysine (5 percent) and deficient in methionine (0.7 percent).

An extensive study made at Colorado College showed marama essential amino acid content is also comparable to soybean. Indeed, its protein proved superior in nutritional quality to most common legume crops, such as garden bean and pea. It had more albumin and less globulin than soybean protein, making it more digestible and more readily available to the body.[2]

The seeds are a great source of food energy as well. Oil content is reported as 36-43 percent of the dry seed by weight. Thus, its oil content is about twice that of soybean, and approaches that of peanut.

The seeds are not only a good source of protein and energy but of nutritionally important minerals and vitamins, including potassium, phosphorus, thiamin, riboflavin, and nicotinic acid as well. They have less than half the fiber of peanuts, a feature both good and bad.

The edible underground portion of the plant is also nutritious, with tubers containing about 9 percent protein dry-weight.

HORTICULTURE

The plants are propagated by seed, which germinate readily in moist soil if scarified; soaking, however, rots them. Sprout-propagation has been done experimentally. Leaves often die back under drought or cold, but the storage root allows them to regrow quickly. This adaptation builds up root storage

[2] Bower, N., K. Hertel, J. Oh, and R. Storey. 1988. Nutritional Evaluation of Marama Bean (*Tylosema esculentum*, Fabaceae): Analysis of the Seed. *Econ Bot* 42:533-540.

and reduces moisture losses due to transpiration. Beyond this, little has been reported on the means of managing a sprawling marama crop. It may turn out that some growers focus on seed production, and others on tubers.

HARVESTING AND HANDLING

Currently, seeds are picked and tubers dug by hand. Raw seeds store well and remain edible for years. Roasting them in their shells makes them easy to open. Before eating, the beans must be carefully peeled.

LIMITATIONS

This plant is so neglected that the very lack of knowledge is perhaps its major limitation. Before wide-scale cultivation could be undertaken with any degree of confidence, information is needed on its adaptability to cultivation and on all aspects of its agronomy. Other limitations include the following.

While the plant has a wide distribution, it occurs patchily in very localized stands, perhaps indicating special soil requirements. Sand seems to be the common denominator. And that makes sense with a crop whose tuber needs to swell and not be restricted by soil pressure.

Even under good conditions, seeds may appear only after 2-4 years, and it may take as long for tubers to reach marketable size, after which they can become fibrous and astringent. Some tubers also have a tough, leathery skin.

Some writers have reported that the seeds can taste slightly bitter and that the hard shell surrounding them is a hindrance to their use as oilseeds. According to one correspondent, an excess of roasted seeds has a strong purging effect, but this is not widely reported.

Like soybean, the marama contains a potent trypsin inhibitor activity. This occurs in the protein fractions (both water-soluble and saline-soluble) and is destroyed by the heat of normal cooking.[3]

NEXT STEPS

Of course the marama is still a long way from being a cultivated plant. Even in their native region the bean is not a firmly established article of commerce. This means that there are many things to be done. In fact, this plant needs to be attacked on several knowledge fronts.

Protection Wild stands offer a wealth of different germplasm, but are being exterminated in many areas. For one thing, the land is being plowed and planted with maize or sunflower. For another, the seeds are being relentlessly harvested for village use and for sale. A third threat comes from the cattle ranching that now extends deep into the Kalahari region, as livestock eagerly devour the plant’s leaves and runners.

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[3] Ibid.

Documented and approved germplasm collections should be made immediately and desirable strains selected. Initially, strains should be selected on the basis of productivity; to date, no single yield, measured or estimated, is reported. Vigorous strains producing large numbers of pods, bigger seeds, or more seed per pod could change the whole picture of the plant's future. Furthermore, strains that yield especially well under adverse conditions should be sought in the harshest sites.

In a related vein, the wisdom of the Kalahari peoples needs to be compiled in easily accessible form. As traditions are abandoned in favor of agricultural, pastoral, or industrial activities, their intimate knowledge of the bean and its use is being lost. Some of this has been done already, and those records need to be extracted from obscure and inaccessible reports and made accessible to plant scientists and others—*especially these peoples themselves*—who can help foster the marama's progress.

Use of the Wild Resource This plant seems an ideal tool for battling the scourge of desertification. This is a spreading species that sprawls across the land, protecting the soil from wind, rain, and sun. For the support of traditional cultures and ways of life, marama could be an outstanding tool. If production could be increased in the Kalahari, many would benefit.

Food Technology Storing and processing the seed (especially dehulling) needs better understanding. Temperature, loss of nutritional value, rancidity, and other effects on quality also need documenting.

The residual meal left after oil extraction contains about 50 percent protein and should be valuable for food and feed uses, but nutritional and analytical trials are necessary to undercover any undesirable factors.

Horticultural Development Marama bean is not yet ready for large-scale cultivation but agronomic research is nonetheless badly needed. Among features deserving investigation are the plant's requirements for altitude, temperature, moisture, soil type, fertilization, and latitude. Processes for enhancing growth also require documentation.

In addition, trials are needed for learning how to manage the plant as a crop. Cultural practices such as germination, spacing, planting, weeding, and pest and disease control all need study and evaluation.

Genetic improvement needs particular attention because today the plants produce too little seed for the fraction of the field they occupy.

Physiological Studies Because of this plant's special importance for semiarid climates, botanists could provide useful information by detailing the mechanisms that allow it to survive extreme heat and desiccation. Temperatures sometimes reach 50°C in its native habitat and surface water is available usually for only 8 weeks a year.

Below ground, marama produces a tuber much bigger even than sugar beet and much more nutritious even than potato or yam. Compared with those and other root crops it is high in protein, containing about 9 percent on a dry-weight basis. (A.S. Wehmeyer)

Tuber Development The tubers warrant particular attention: composition, growth rate, occurrence of nonastringent types, and production potential in small plots should all be investigated.

Harvesting In the long term the greatest barrier to development of this plant may prove to be the mechanical one of how to gather the crop, both seed and tuber, from this sprawling, awkward-to-handle plant.

SPECIES INFORMATION

Botanical Name *Tylosema esculentum* (Burchell) A. Schreiber

Synonyms *Bauhinia esculenta* Burchell

Family Leguminosae - Caesalpinioideae

Common Names

Afrikaans: Braaiboontjie, elandsboontjie pitte, gemsbokboontjie
English: gemsbok bean, gemsbuck bean, tamami or thamani berry
Thonga: marumama
!Kung: tsi, tsin
Khoi-khoi: gami
Herero: ombanui
Tswana: marama, marami, morama, lai, muraki, litammani, rama, tammani

Description

The plant is not a climber; it grows prostrate, sending viney stems creeping out over the soil surface in several directions. These runners are up to 6 m long and form a dense, geometrical pattern of overlapping whorls of stems, hugging the ground, presumably to avoid the drying winds. The vines carry double-lobed leaves that are soft and red-brown when young, turning leathery and gray-green with age. Golden-yellow, insect-pollinated blossoms develop in midsummer (December/January in southern Africa) and the fruits ripen in late autumn (April).

Each fruit comprises a large, flat, woody pod enclosing one to six large beans. The pod starts out soft and reddish-brown, then turns light green and, when ripe, becomes chestnut-brown and woody. Each bean has a hard inedible outer shell and an edible two-lobed seed inside. Though hard, the woody shell is thin, brittle, and easily cracked. The normally spherical seeds are roughly the diameter of a thumbnail and weight about 2-3 g. Their inner flesh is firm, cream colored, oily, and almost without fiber.

During cooler months, the stems may die back but the underground tuber remains viable and, with returning warmth, shoots forth more stems. After a few years the tuber can weigh more than 10 kg. It can contain 90 percent water by weight. Tubers more than two years old become fibrous and/or astringent. In deep, loose, sandy soils, the plant is reported to form “craters,” sometimes over a meter across. These hollows in the landscape are often ringed with stones that appear to have been forced to the surface by the giant tuber swelling beneath.

The plant is a legume but it belongs to subfamily Caesalpinioideae and, like many of them, it fails to nodulate and fix nitrogen.

Distribution

Within Africa Occurs in the northern part of Namibia, Botswana, as well as the western and northwestern Transvaal and the northern Cape in south Africa.

Beyond Africa Reported in California, Texas, and Florida in the USA, Queensland in Australia, and Israel, and some botanic gardens. It has curiously become a favorite of some bonsai enthusiasts, so probably now has a broader, yet still small-scale distribution.

Horticultural Varieties

None reported.

Environmental Requirements

The marama survives in regions where few conventional crops survive, yet it appears adapted to a wide range of climatic conditions. Obviously, the plant's environmental requirements are at present far from certain but the following seems a reasonable summary.

Rainfall Mainly, marama grows where rain is so slight and erratic that in some years almost no moisture falls at all. In some locations, even in the best of times, the rains last for only two months a year. The sparse precipitation arrives during short-lived torrential thunderstorms in spring and fall. The rest of the year remains almost rainless. Usually, however, there is subsoil moisture that the deep roots tap into. Indeed, in fine-grained sandy soils, water may remain in the root zone for months after rain. Marama also exists in well-watered locations receiving up to 800 mm annual rainfall.

Altitude The plant is found in a region lacking in mountains, but altitude seems hardly likely to be a limitation by itself.

Low Temperature In winter, when the plant is dormant, temperatures plunge very low (by African standards). Winter nights can be freezing and the days frosty.

High Temperature Very high summer temperatures to 47 °C in the shade and sometimes over 50° have been reported.

Soil Marama beans prefer neutral to acid soil. It is particularly prominent on the brick-red sand of the inland Namib Desert. Grows on deep sand but also where there are outcrops of dolomite; also has been grown on neutral shaly soils.

Related Species

Two related species may also be worth agronomic attention.

Tylosema fassoglense Grows from the Transvaal north through Central and East Africa to Sudan. This sprawling vine also yields edible seeds plus excellent livestock forage and a tuber with a wide variety of traditional medicinal uses. Like marama, the seeds are very high in protein (> 40 percent) and fats (> 30 percent), and widely appreciated.

Bauhinia petersiana A small shrub that grows together with the marama bean in open grasslands (as well as in sandy bushveld and woodlands) in Transvaal, Namibia, and Botswana, as well as in Angola and Zambia. The seeds can be eaten green, but ripe seeds are usually roasted, peeled, and pounded into a pleasant-tasting, coarse meal. The plant has been cultivated as an ornamental in South Africa and, given research, might also become a useful food crop for arid zones.

14

MORINGA

Although few Westerners have ever heard of it, moringa is potentially one of the planet's most valuable plants, at least in humanitarian terms. Perhaps the fastest growing useful tree, it commonly tops 3 m—or even 5 m—within a year of the seed being placed in the ground.[1] Some people actually grow it as an annual.

Strangely, this tree is raised for food rather than forestry. A sort of supermarket on a trunk, it yields at least four different edibles: pods, leaves, seeds, and roots. And beyond edibles, it provides products that make village life more self-sufficient: lubricating oil, lamp oil, wood, paper, liquid fuel, skin treatments, and the means to help purify water, to name but a few. The living tree, itself, also provides such things as shade, landscaping, and shelter from the elements.

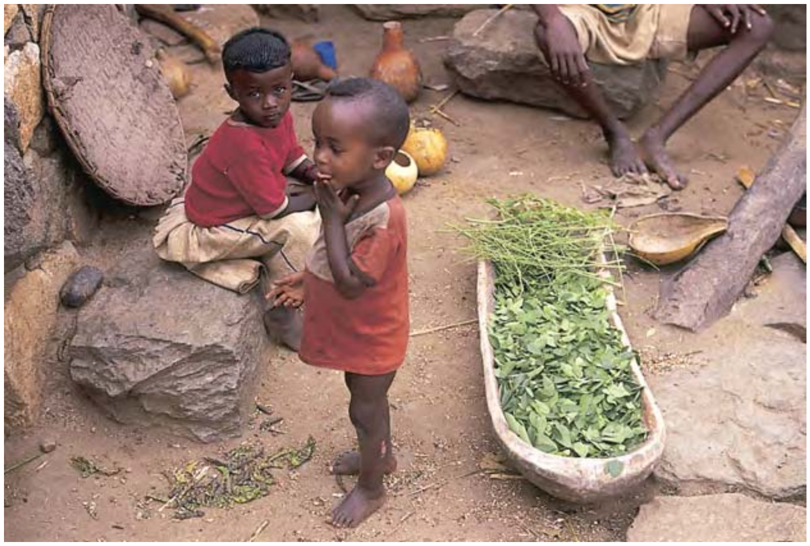
Arguably, this multi-tasking species is the most exciting tropical resource still awaiting widespread application. And it is a supreme poor-person's plant with promise for benefiting much of rural Africa. Not without reasons do aficionados refer to it as "mother's best friend."

Foreigners who have read about the seemingly wondrous moringa are usually disappointed when they finally get to see one. Except under the best of conditions, it is far from handsome. Indeed, it typically is small, scrawny, wispy, and wholly unimpressive to the eye. Partly that is because people forever pick it for food, but even the most pampered specimens will never be confused with the forest giants of popular imagination. All in all, this is a down-to-earth, unpretentious, and unsophisticated member of the tree world.

But this "working-class" species works, and it works well. Some varieties flower profusely and are used chiefly to produce young pods; others flower sparsely and principally yield leaves. In both cases production can be outstanding. A single tree grown under good conditions can, for instance, bear more than 1,000 pods a season and can supply leaves year round if the climate is conducive.

Of all moringa's edible parts, the green young pods are most sought-after. These legume-like fruits are typically 30-60 cm in length and are

[1] Roy Danforth wrote from Congo: "The trees grow much more rapidly than papaya, with one 3-month old tree reaching 8 feet. I never knew there could be such a tree."



Village of Kolme, Konso, Ethiopia. Moringa yields at least four different edibles: pods, leaves, seeds, roots. Next to the green pods, foliage is the most important food product. People in various countries boil up the tiny leaflets and eat them like spinach. Taken all round, this supreme poor-person's plant shows a remarkable capacity to help solve problems such as hunger, malnutrition, rural poverty, disease, deforestation, and visual blight. The leaves here are *Moringa stenopetala*, a cultural heritage and domesticated plant of the Konso people. In this region of southwestern Ethiopia its leaves constitute an important part of their diet. (E. Demeulenaere)

usually served as vegetables. Looking like giant string beans, but tasting somewhat like asparagus, they are highly nutritious. For one thing, they provide a good balance of all the essential amino acids. That alone is unusual in a plant food, but these pods also possess one of the highest vitamin C levels of any tropical vegetable, not to mention goodly quantities of vitamins A and B. And beyond all that they are among the best sources of minerals.[2]

Foliage is the next most important moringa food. People in many countries boil up the tiny leaflets and eat them like spinach—a spinach that nature has chopped to confetti size. In the Philippines, where moringa is exceptionally popular, these boiled leaves are commonly fed to babies. Nutritionally speaking, they are remarkable for methionine and cystine. Both are essential to health, and both are among the hardest amino acids for the

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[2] A current summary and analysis of moringa nutrition, along with an overview and information on cultivation and food preparation, is Fuglie, L.J. 1999. Moringa oleifra: *Natural Nutrition for the Tropics*. Church World Service, Dakar; available on-line at churchworldservice.org/moringa/miracletree.html.

body to acquire from plant-based diets. Moreover, moringa leaves contain vitamins A and C, more calcium than most other greens, and so much iron doctors prescribe them for anemic patients.[3] And regular consumption of the leaves is reported to increase milk production among lactating women.

Because of discoveries like these a number of development organizations around the world are actively promoting moringa leaves and dried leaf powder as nutritional supplements. The leaves are remarkably easy to handle. Unlike many other leaf crops there is no fibrous leaf stalk (petiole) to be removed. The leaflets are thus 100-percent edible. And with more than three times the dry matter of spinach, they dry quickly and easily.

The thick, soft roots are probably moringa's third most important food resource. They are a popular condiment, with the flavor of horseradish, for which they are employed as a substitute. Other parts of this plant provide useful food items too. The shoot tips, flowers, and even whole seedlings make boiled greens that are similarly high in protein, vitamins, and minerals. Finally, the pods that are too old and tough to be eaten like green beans are employed as a snack—slit open and the sweet, frothy, white pulp sucked out.

Perhaps the most innovative and provocative use of this already innovative and provocative species is to treat water and wastewater. The protein found in moringa seeds can be used to settle silt and other contaminants. Research in Africa has disclosed that it can replace alum, a normally imported and expensive material. The water still needs a final filtration but the seeds make the process easier and more complete, while extending the useful life of water filters. This could be of major significance where water-borne diseases are prevalent and where central water treatment systems are creaky or nonexistent.

The genus *Moringa* is a small one whose center of biodiversity is the Horn of Africa.[4] The best-known species, *Moringa oleifera*, must have sprung from those East African "proto-roots" although it apparently completed its evolution across the Indian Ocean, in the foothills of the Himalayas. So although not African itself it derives directly from African stock. The following text relies mostly on this species (for the reason that it

[3] Researchers summarizing moringa put it this way: "...among the leafy vegetables, one stands out as particularly good. It is the horseradish tree, *Moringa oleifera*. The leaves of the tree are outstanding as a source of vitamin A and, when raw, vitamin C. They are a good source of B vitamins and among the best plant sources of minerals. The calcium content is very high for a plant. Phosphorus is low, as it should be. The content of iron is very good. They are an excellent source of fat and carbohydrates. Thus, these leaves are one of the best plant foods that can be found." Martin, F.W. R.M. Ruberte, and L. Meitzner. 1998. *Edible Leaves of the Tropics*, 3rd ed.; available via ECHONet.org.

[4] There are 13 species in the genus. Nine occur in eastern Ethiopia, northern Kenya, and Somalia (8 occur nowhere else). The densest concentration is Kenya's northeast corner, where 4 species are found. Two more occur in Madagascar and 1 is endemic to Namibia and southern Angola. Only 1 of the 13 species, *Moringa oleifera* itself, seemingly arose full-blown outside Africa. Information from Mark Olson.

is the only one about which much information is available). Nonetheless, it seems more than likely that the chapter's statements are at least generally relevant to *M. stenopetala* and perhaps also to the other species (see later), which presently remain all but unknown to experimental science and the technical literature.

Whether or not it has direct African roots, moringa could certainly prove beneficial to Africa. Taken all round, it shows a remarkable capacity to help solve problems such as:

Hunger An ability to provide so many different foods makes this tree potentially valuable for the needy and destitute. It yields up its bounty at little cost to, or effort from, the growers.

Malnutrition The pods and leaves are among the most nutritious foods to be found in the plant kingdom. In West Africa the leaves appear at the end of the dry season, when there are few other sources of leafy green vegetables. Several programs already promote production of moringa leaf powder for use in sauces or as a general food additive.

Rural Poverty Potentially there is profit in moringa. First, this is a fast-growing, high-yielding oilseed. Second, the trunk is gaining importance as a raw material for papermaking. And third, pods can be produced for the fresh market or for processing.

Public Health With its mother lode of vitamins and minerals, moringa is virtually a nutritional supplement for farm or village. Exceptional levels of iron and calcium should make it particularly valuable for women young and old. Adding to its public-health benefits is that its seeds can help purify water. There are also indications that seed extracts are useful treatments against skin complaints.

Deforestation This species is not a foresters' tree but its ability to thrive in wastelands and provide rapid shade cover could make it the choice for many tree-planting projects. Likely, too, it is a good nurse crop for slower-growing species that eventually will dominate the site.

Visual Blight Moringa is an excellent candidate for fast-track beautification of streets, slums, and squatter settlements. The average specimen looks like an arborist's nightmare, but a little care can endow it a pleasing rounded appearance. Interestingly, it might help de-uglify the megacities that are projected to dominate the future of the tropics, and make them more livable.

Overall, moringa is easy to use. It is particularly valuable for planting for

and by the young, the poor, and the landless—in schoolyards, parks, roadsides, bus stops, cemeteries, and so on. It likely has a special role in the camps for displaced persons now all too prevalent in many parts of Africa. This rugged, resilient species tends to produce well in marginal growing conditions and is a reliable source of greens in seasons and locations where few other vegetables can produce much of anything. In equatorial areas, it bears food almost year-round. With hunger, malnutrition, poverty, disease, deforestation, and visual blight so widespread, now is the time to bring this tree fully into the fold of African—nay, world—crops. Success seems likely to be not only quick but comprehensive.

PROSPECTS

Despite the previous neglect, this species seems poised to rise to take a major role in many facets of rural life in the world's warmer regions.

Within Africa

Humid Areas For the wet tropics moringa could be a most useful resource. This is not its traditional habitat, but the plant seems well adapted to hot, humid conditions and, at least in certain areas, has thrived under annual rainfall exceeding 3,000 mm.

Dry Areas Moringa is especially adapted to dryness and may resist several months of drought, probably because its swollen roots store water. It has survived, for example, blistering heat, desiccating drought, and depleted dunes in places such as Sudan and the Sahel.

Upland Areas Originally, moringa was recommended for planting only at altitudes below 600 m. However, the discovery of healthy stands at elevations of 1,200 m in Mexico and over 2,000 m in Zimbabwe has demonstrated that it is much more adaptable than supposed. It withstands light frost but is seriously harmed if temperatures dip 5°C below freezing for even one evening.

Other Regions

Some may at first balk at picking table greens from a tree, but for the hot and hungry corners of the tropical belt any such reluctance is likely to be temporary and will hardly keep moringa from quickly becoming invaluable.

USES

This living cornucopia can provide various means to a better life in the hot, harsh rural regions.

A rugged, resilient tree species, moringa tends to produce well in marginal growing conditions and is a reliable source of greens in seasons and locations where few other vegetables can produce much of anything. In West Africa the leaves appear at the end of the dry season, a time when other sources of leafy green vegetables have mostly died. Here, an older tree produces abundantly in the highlands of Oaxaca, Mexico (Mark Olson - explorelifeonearth.org)

Immature Pods As has been noted, the tender young pods have the general characteristics of a succulent string bean. They may be eaten whole but for ease of use most are sliced and diced before cooking. In India, these long thin vegetables are a common fare, frequently added to curries and even sliced, blanched, canned, and peddled in thousands of markets and stores. There is even an international trade in both fresh and canned pods. India, Sri Lanka, Taiwan, and Kenya for instance export them to Asia, Europe, and the United States, where they end up mainly in ethnic Indian groceries.

Mature Pods As the pods mature, they quickly turn tough. Even by the time they are as thick as a pencil they are often too fibrous to eat like string beans. In that form, they are called drumsticks, and are typically cut into pieces and the sweet frothy inside material is slurped out. Throughout India drumstick slices are well-known ingredients in pickles and in Madras they are common also in the famous drumstick curries.

Leaves The foliage is fernlike, with myriad tiny leaflets produced in abundance through most of the year. The feathery leaves are easily stripped to separate the leaflets, which are 1-2 cm in diameter. The young ones are particularly prized in the Philippines, where certain ethnic groups proudly associate their whole culture with the plant.[5] In addition to being boiled like spinach, they are dried, crushed, and sprinkled on food.[6] In many areas of Africa, people have found the leaves easy to preserve by air-drying (which should be done indoors since sunlight destroys vitamins A and C).

Seeds The soft seeds extracted from immature drumsticks are boiled and eaten like fresh peas. Fried, they taste like peanuts. Only immature white seeds are eaten (either boiled or fried). Once they ripen, the taste turns bitter.

Roots The pungent fleshy root is pulverized into a flaky condiment with a horseradish bite. This has given moringa the widely used name “horseradish tree.” The thick, soft roots are also pickled. For this, they are peeled, dried, ground, and steeped in vinegar.

Seedlings Young seedlings are pulled up, boiled, and eaten whole.

Flowers The flowers, which occur year round in some places but are more often seasonal, are cooked as a vegetable and are sometimes steeped in boiling water to yield a fragrant tea. In Kenya’s Kibwezi region, farmers fry the flowers and liken the taste to that of fried egg.[7] Raw, they have a strong or hot radish-like flavor. In Oaxaca, Mexico, poor people have adopted the tree solely as a source of white flowers for decorating churches and houses on religious festival days.

Honey A good bee tree, moringa begins flowering at a young age. Specimens from seed usually flower within 2 years; those grown from

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[5] One example is the Illocano people of northern Luzon.
[6] One West African hospital is drying and powdering the leaves, then giving the powder as a prescription when a malnourished child comes in. Parents are instructed to mix it with the baby’s food. Such usage is also spreading quickly elsewhere.
[7] Information from D. Odee.

With its mother lode of vitamins and minerals, moringa is possibly the planet's most valuable undeveloped plant, at least in humanitarian terms. Regular pruning can maintain a compact form whose leaves are easily harvested (left). New leaves are produced in abundance almost daily (center), or plants can be managed to produce pods (right). Intensive management such as this can give impressive, sustain yields in a small space. (Neofarming - moringa.com.tw.)

cuttings have been known to flower when only a few months old.[8] Then, as long as the climate is conducive, they bloom continually for years on end. The resulting honey is tasty, clear, and often consumed as a medicine.

Fodder Livestock relish the foliage so much that in some regions moringa is an important fodder. In India, for example, water buffaloes are fed the chopped up leaves and branches, which are said to boost milk production. Trials conducted in Nicaragua found that range-fed cows gave a 30-percent increase in milk and meat production when their diet was supplemented with 45 percent moringa forage.[9]

Oil Pressing the seeds produces a pale-yellow oil. Alternately, seed can be boiled in water, in which case the oil floats to the surface where it can be skimmed off. Oil makes up 20-40 percent of the seed—a reasonable quantity. It is a valued base for ointments since it lacks color, smell, and taste, and turns rancid only slowly. These same properties make this non-drying oil useful for enfleurage, the process by which perfume companies extract flower fragrance. Because it absorbs and retains delicate scents, it is also valued in products like hair oil. It was once traded internationally ("ben oil") for lubricating the wheels of clocks as well as making oil paints for artists. More recently, it has shown particular value for making quality soap.

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[8] In Kenya moringa has flowered **and fruited** in 3 months. Information from D. Odee
[9] Information from L. Fuglie.

Fuel Moringa oil is said to equal the best lamp fuel, burning with little scent or smoke and emitting a light both bright and clear.

Gum When wounded, the bark exudes a polysaccharide used like glue.

Wood Although soft and spongy and not a great fuel, the wood burns cleanly and gives off little smoke or smell. White and tasteless, it also makes good chopsticks, and provides a pulp suitable for newsprint as well as wrapping, printing, and writing papers, not to mention the viscose rayon used in textiles and cellophane.

Shelter, Shade, and Privacy Screens Though never showy, this tree is not unattractive. People sometimes plant it to ornament gardens as well as highway verges. Its airy foliage casts only light shade. Planting a line of seedlings produces a living fence that can become a seamless line in as little as a year. For even faster results, sizable branches can be set upright in the ground to form an "instant hedge."

Agroforestry The tree is good in agroforestry and mixed cropping. The thin shade helps protect vegetables in the hot tropical sun. Because of its downward rooting pattern, there is little competition with associated crops.[10] In sum, this seems to have the making of an ideal agroforestry component.

Water Purification Inside each pod are found up to 25 seeds, which yield a quality vegetable oil and in crushed form they can be used to help clarify turbid water. Charged proteins in the seed tissues coagulate suspended particles, precipitate disease organisms, and generally help turn a dangerous muddy muck into a clear potable liquid.

Medicinal Uses Many supposedly effective folk remedies incorporate moringa. The pulp of the root, for instance, is used like a "mustard plaster." The crushed seed has been recommended as an ingredient in ointments because it demonstrates anti-microbial activity.

NUTRITION

Most parts of this plant are more than just edible; they are nutritious.[11] Moringa, unlike most foods in this report, has been analyzed in many studies that support high (though highly variable) levels of carbohydrate, protein,

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[10] Information from D. Odee.

[11] Much information in this section is based on the detailed review of Fuglie, op. cit., and Gopalan, C., B.V. Rama Sastri, and S.C. Balasubramanian. 1971. *Nutritive value of Indian foods*. National Institute of Nutrition, Hyderabad (revised and updated in 1989 by B.S. Narasinga Rao, Y.G. Deosthale, and K.C. Pant).

and especially vitamins and minerals. It has been said, for example, that: "As sources of the usually short sulfur-bearing amino acids methionine and cystine, *Moringa oleifera*, grown for edible leaves, shoots, young fruits, and roots, is incomparable."[12] Methionine and cystine are arguably the most critical dietary ingredients for people lacking regular access to meat, milk, cheese, eggs, or fish.

Leaves Leaves are eaten fresh or dried as a storable powder (in which process they can lose much of their vitamin C). On a dry-weight basis, both have more than 200 calories (up to 400 is reported), with about 30 percent protein and 1-2 percent fat. Nutritional trials with laboratory rats show that the leaf is an excellent supplement to rice and other staples. In addition to being rich in overall protein these leaves also, as noted, provide methionine and cystine. A modest helping (100 g dry-weight) generally provides at least an adult's daily requirement for provitamin A. The leaves are also supply good folate and other B vitamins. Further, they are among the best plant sources for dietary minerals, especially calcium (up to about 2000 mg) and iron approaching 30 mg, about twice the level of spinach and exceeding even the amount in patent medicines touted for stimulating pep and vigor.

Pods On a dry-weight basis the protein content of moringa pods ranges from 20 to 30 percent—an amount well above average for a vegetable. Moreover, vitamin C content is so high that a 50 g serving (or less) provides an adult's daily needs. In addition, minerals seem to be in good proportion. Iron—often deficient in African diets—is as high or higher in the pods than in the leaves, although the level probably depends on site conditions and preparation. The content of copper also seems notable (though highly variable and requiring confirmation).

Seed Oil The liquid making up a quarter to almost half the seed's weight is not unlike olive oil in composition. In one analysis of the fatty acids, the seed oil contained about 66 percent oleic, 9 percent palmitic and behenic, and 7 percent stearic.[13] The nutritional contribution of the oil itself to meager diets could be significant.

HORTICULTURE

This tree generally grows satisfactorily, but just how to grow it best is far from certain. Outside certain regions of India, where large-scale cultivation is practiced, the tree receives little professional horticultural attention and has not been subjected to formal comparative trials.

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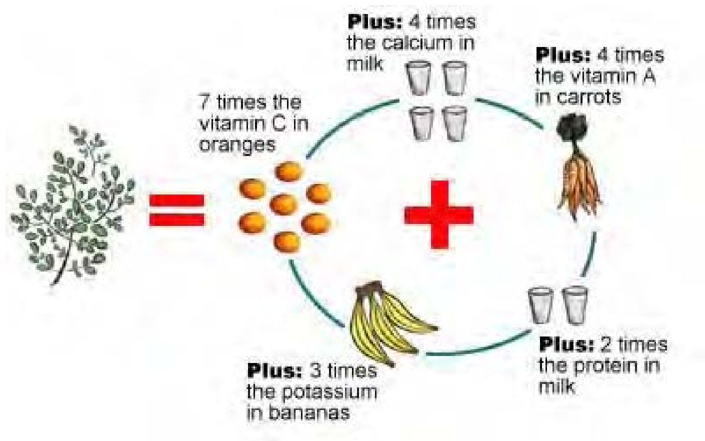
[12] Martin et al., op. cit.

[13] Sastri, B.N., ed. 1962. *Wealth of India: Volume VI.* Council of Scientific and Industrial Research, New Delhi.



Gram for gram, fresh moringa leaves outperform these well-known nutritional champions, and they taste good too. (TreesForLife.org.)

Moringa can be propagated through seed. No pretreatment is required and seeds sprout in only a few days in prepared seedbeds, a week or two in the field. However, this species is mostly (and most easily) propagated via cuttings. Even sections of branches as long as an arm will root in moist soil, becoming tree-like in just a few months and producing fruit within a year. However, trees grown from cuttings tend to have short and spreading roots.

Mulching and fertilizing improve production and quality of the leaves. In addition, heavy pruning encourages lateral shoots and increased leaf production. Pruning tops (at about head height) provides for easy harvest.

By and large, diseases or pests seldom affect the tree seriously. In India, a foot rot (*Diplodia*), a bark disease (*Indarbela*), and a defoliant are reportedly problematic. Also, caterpillars sometimes leave the tree leafless and termites sometimes tunnel into the trunk. Termites (*Macrotermes* spp.) can kill mature trees, especially during prolonged droughts. When planted in very wet conditions, it may suffer root rot.

A contributor has passed on advice for making eye-catching moringas: “This awkward tree can actually be quite attractive if the tip is pinched out when the tree is perhaps 2 meters tall, and the side shoots likewise pinched when they have grown some. This forces a rounder canopy. We grow it that way and use it as a light shade for vegetables that do not do well in the full tropical sun.”

HARVESTING AND HANDLING

The tree withstands heavy cutting and can provide a continuing supply of wood, fodder, and other products. Both coppicing (continual cutting near the

base) and pollarding (continual cutting higher up the trunk) are possible. One recommended system is to set the trees about a meter apart and trim them regularly like a hedge to provide successive crops of leaves.

Plants raised from cuttings bear in 6-8 months after planting. The pods are usually taken directly from the trees individually by hand.

The leaflets are easy to harvest by stripping them off between thumb and forefinger. As already noted, there is no leaf stalk to be removed and the leaves dry quickly and easily.

LIMITATIONS

Many (even most) of the trees now scattered throughout the tropics are pale shadows of the top-performing types. Plants raised from seed often produce inferior pods because of intercrossing with bitter-tasting wild types. Thus for quality crops, vegetative propagation is a must.

The pods must be picked at the right stage because within a day or two they toughen up and turn stringy. Unfortunately, it is not easy to tell (in words) exactly when a pod is at the point where it is ready to pick.

Termites in some areas may limit the tree's culture. Leaf-cutting bees sometimes strip a tree of almost all its greenery. Browsing animals are also a threat. Both livestock and wild herbivores consider moringa to be like candy, and can destroy a new planting overnight. Pigs have been known to dig out even established trees to feast on the tasty roots.

The tree's limbs are weak and break off easily, especially when laden with pods. The soft, almost spongy wood is slow to dry and very susceptible to termite attack, so it is not useful in construction.

The horseradish substitute from the roots must be made with care because the bark evidently contains alkaloids. To eliminate any possibility of toxicity, careful peeling is needed. Indeed, this usage as a peppery condiment may not be safe at all.

NEXT STEPS

Any tree that can provide food to the hungry parts of the planet could be the subject of massive plantings and major initiatives. Such projects need to be undertaken; some are already in action and have much to teach that is positive. In West Africa, Church World Service (CWS), has helped establish over 70 hectares of moringa plantings and is creating a farm for intensive production of leaf powder. In Tanzania, Optima of Africa is growing thousands of hectares of moringa for production of oil and of the flocculent used to clarify water, and Trees for Life has projects in many Asian and tropical American countries. A quick Internet search reveals many others.

Publicity With all the potentials, it is hard to imagine why there aren't million-dollar moringa-promotion programs with international backing.

Foresters probably shun it because it is basically a food crop; agronomists because it is a tree; fruticulturists because it is a vegetable. The combined neglect has reached such a pass that in many countries hungry people don't even realize that the moringas growing around them are edible. Even where millions are malnourished or starving the plant's nutritious products often are wasted. Haiti and Sudan are just two examples where this good food goes begging. In both cases the tree was introduced as an ornamental and the fact that it provides life-giving nutrients remains mostly unrecognized. Local and international efforts are needed to provide information, publicity, and greater awareness of this tree and its capabilities—particularly to the people on the ground and their supporters.[14] Introduction of good genotypes for multi-location testing is also required.

New Plantings In each of the several dozen appropriate countries—especially those facing chronic malnutrition—a rapid search (rather than a time-wasting, exhaustive one) should be made for adequate moringa types, which should then be vegetatively propagated and planted out in nurseries and observational trials. A few groups are already way ahead on this and have such trees already selected and planted out. The Kenya Forestry Research Institute, for instance, has initiated such a program and is also developing seed orchards of improved material for specific purposes and end uses.[15] But many more groups across many African countries should be also exploring this most promising resource.

From these "foundation banks" seeds or cuttings can be taken and distributed to farmers, homeowners, and others. In all of this there are good chances for both humanitarian success and small-business development. Moringa cultivation should be particularly promoted in the slum areas of cities, where small plantings should prove of immediate benefit to children (see below).

Nutritional Interventions Throughout Africa, moringa could be immediately incorporated into programs tackling the misery of malnutrition. It is reported by CWS that three spoonfuls of moringa leaf powder (about 25g) contain 300 percent of a typical toddler's daily vitamin A requirement, along with 42 percent of the protein, 125 percent of the calcium, 71 percent of the iron and 22 percent of the vitamin C. It also contains a full complement of minerals and amino acids.

With four times the beta-carotene of carrot, moringa has especial potential for programs dealing with avitaminosis, the vitamin A deficiency

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[14] Moringanews (moringanews.org) is one such international network of people interested in moringa; their website offers a wide variety of documentation on moringa, and a platform to exchange knowledge, products, and services.
[15] Information from D. Odee.

Moringa produces seed in abundance. Immature seed is relished fresh, boiled, or fried. Mature, it yields a very pure oil widely used in cooking as well as for energy and quality lubrication ("ben oil"). The remaining meal has proven to be a powerful home-grown water-purifier whose use is rapidly expanding in many parts of rural Africa. (Neofarming - moringa.com.tw.)

that causes 70 percent of childhood blindness.[16] Other diseases caused by the lack of nutrients that are abundant in moringa include beri beri, rickets, and scurvy. There's already some precedent to follow: Since 1996, for instance, CWS and local partners have been actively promoting moringa for improved nutrition in Senegal. Based on CWS research funded by the U.S. Agency for International Development, many health centers now stock moringa leaf powder in their pharmacies for use in treating cases of moderate malnutrition.

The seed oil could become a valuable nutritional commodity with the ability to extend diet and provide cooking oil from a readily available local source.

Horticultural Development While such major initiatives are under way, more basic studies are also needed to provide better materials and more reliable guidelines for long-term use. Three examples are:

Genetic Improvement Almost certainly moringa can be selected and improved in ways that produce separate cultivars for top-quality vegetable

[16] The International Eye Foundation is using moringa this way in Malawi.

oil as well as for various tasty and nutritious vegetables from fruits and leaves. Hybridization between elite types might also be carried out. Elite cultivars of course require vegetative propagation. In India, over 85 types of moringa have been developed to reflect local tastes in pod size and shape. Many of these types are grown for one to three years, and then replaced with new trees on a regular rotation, almost as if they were biennials.

Genetic Diversity This immensely useful tree's genetic variability needs careful assessment. Although many types exist, no one presently knows which are best suited to various uses, environments, and local needs. Much genetic diversity is especially available in the Terai region of India and Nepal, as well as Uttar Pradesh in northern India. Surprising genetic diversity has also been located in century-old material in eastern Africa.[17]

Agronomy There needs to be more exploration into the most favorable conditions for cultivating moringa. The plant seems to grow well under many different conditions and in many different soils, but no one knows its optimal requirements or its limits.

Water Purification Lack of drinkable water is, arguably, the world's biggest health threat. In the rural regions of many developing countries, people must take drinking and washing water from rivers, wadis, swamps, lakes, and even hollowed-out tree trunks. Using moringa seed to clarify such supplies should be more widely tested and, where appropriate, used. The science behind it has already been pinned down enough to proceed in this way. Two groups have already made spectacular advances in our understanding of the process.[18]

One of these pioneers has discovered that oil plays no part in the water-clarification process. He now recommends introducing small-scale moringa-seed extraction in the rural areas. Pressing the seeds provides the valuable oil *as well as* the presscake (solids residue after oil extraction) containing the charged proteins that effect water clarification. He now sees the coagulant as the byproduct of high-quality oil extraction.[19]

Other Uses The economic feasibility of employing the wood for paper pulp deserves pantropic exploration. By most standards the wood is poor, but the tree grows fast and might become extremely valuable wherever other

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[17] Information from D. Odee.

[18] These groups have worked extensively in Africa, but are centered at the Deutsche Gesellschaft für Technische Zusammenarbeit in Germany (Samia Al Azharia Jahn) and the Engineering Department, University of Leicester, Leicester, United Kingdom (Geoff Folkard). In addition, Rotary Clubs are sponsoring moringa-based water-purification projects in Brazil and Zimbabwe.

[19] Information from G. Folkard.

pulp sources are scarce. Indeed, large-scale moringa plantings are already being established to help meet India's paper shortage. In sub-Saharan Africa there are large tracks of dryland suitable for moringa, but not conducive to other crops; these might perhaps be planted to moringa, thereby protecting the environment as well as generating useful resources, including pulp.

Moringa is potentially useful in alley cropping and contour hedges grown across hillslopes to slow soil erosion. Specimens grown from seed are deep rooted, with few lateral roots to interfere with the neighboring crop plants.

Exploration of the Wild Resource Although the Horn of Africa is the "birthplace" of the genus, only recently have significant efforts been made to explore the *Moringa* species to be found there and the uses to which they are put.[20] In fact, the traditional cultivation of the "cabbage tree" (*M. stenopetala*) was apparently "lost" to science until mentioned for the first time in a geographical paper concerning Ethiopia as recently as 1938. Even today, the tree is maintained inside compounds as well as on terraces, and its leaves are an important vegetable during the dry season. Yet it has never been subject to scientific investigation.[21]

Food Technology In the handling and processing of moringa products, much remains to be done before the tree's full potentials can be approached, perhaps even in India. Examples of two needs follow.

- *Cooking Oil* Many Third World families would benefit enormously if they could grow a quality cooking oil on trees in the backyard. Moringa may not prove the best candidate, but this possibility ought to be explored. Typically oilseeds need to be heated to free up the oil before they are pressed, but this has been found unnecessary in the case of moringa seed—friction generates sufficient heat.[22] This is a boon in that it removes one cumbersome and costly step, and it also means that the oil may be classed as "cold pressed" and touted as a "natural, pure vegetable oil."
- *Seeds* Tests should be done to determine the range of nutritional values for the seeds (and pods), and the potential production of animal feed from the seed meal (the solid left after the oil has been expressed).

Medicinal Uses Moringa is renowned for supposed medicinal properties. A few investigations have suggested there may be some merits to the claims.

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[20] Mark Olson's modern moringa explorations are outlined at explorelifeonearth.org/moringahome.html.

[21] The growers are mainly the Konso, Burji, and Gidole tribes in the highlands south of Lake Chamo in Ethiopia and the Konso and Burji minorities in the Marsabit District in Kenya.

[22] Information from G. Folkard. "One advantage," he writes, "is that if a small extractor is used no external heat is needed."

The root bark, for instance, contains two alkaloids—moringine and spirochine—that act on the nervous system. The roots contain pterygospermin, which inhibits growth of gram-positive and gram-negative bacteria.[23] An old report from Southeast Asia says a decoction of bark stimulates menses and is used for "morning after" birth control. In parts of West Africa, moringa leaves or juice are taken for diabetes and high blood pressure. Some or all of these might have merit, but only careful analysis, sound research, and (if warranted) trials involving control groups and statistical analysis will answer that. Initial investigations seem worthwhile.

SPECIES INFORMATION

Botanical Name *Moringa oleifera* Lamarck

Synonyms *Moringa pterygosperma* Gaertner; *Moringa zeylanica* Pers.; *Guilandina moringa* L.

Family Moringaceae

Common Names

English: moringa, horseradish tree, drumstick tree, sujuna, ben tree, ben oil tree,
French: ben ailé, ben oléifère, benzolive, arbre radis du cheval
Spanish: ben, árbol del ben, paraiso, morango, moringa
Portuguese: acácia branca, marungo, muringa, moringuiero; cedro (Brazil)
Arabic: ruwag, alim, halim, shagara al ruwag (Sudan)
Swahili: mzunze, mlonge, mjungu moto, mboga chungu, shingo
German: Behenbaum, Behenussbaum, flügelsaniger Bennussbaum, Pferderettichbaum
Italian: sàndalo ceruleo
Fon: kpatima, yovokpatin,kpano,yovotin
Gun: èkwè kpatin, kpajima
Yoruba & Nago: èwè igbale, èwè ile, èwè oyibo, agun oyibo, ayun manyieninu, ayèrè oyibo
Adia: kpashima
Mina: Y\yovo vigbe, yovo kpati
Bariba: yuru ara, yorwata yoroguma
Saxwe: kotba

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[23] Few studies have been conducted to validate scientifically their popular use, but two Guatemalan doctors reported making an ointment that proved as effective as neomycin in clinical trials. They used seed from moringa. Ointment can be prepared by extracting the active seed ingredient with very inexpensive equipment and mixing with petroleum jelly. Information from ECHONet.org.

Waama: yori ku-oununfa
Fulani: gawara, konamarade, rini maka, habiwal hausa
Hausa: zogall, zogalla-gandi, bagaruwar maka, bagaruwar masar, shipka hali, shuka halinka, barambo, koraukin zaila, rimin turawa
Ibo: Ikwe oyibo
Tonga: mupulanga, zakalanda
Wolof: neverday, nébéday
Philippines: malunggay or malungai (Tagalog)
India: sujuna, sajina, lopa, horseradish or drumstick tree
Senegal: nebeday
Haiti: benzolive (Haitian Creole)

Description

Moringa is a medium-sized tree that attains about 10 m in height. It has a straight trunk (10-30cm thick) with bark that is whitish or gray, corky, with longitudinal cracks. It also has a tuberous taproot, whose presence helps explain the species' tolerance to drought conditions.

Normally umbrella shaped, the tree comes with a lax crown of graceful, airy foliage, whose feathery effect is due to the finely tripinnate division of the leaves. Those leaves are densely crowded at the tops of the branchlets. Depending on climate the foliage is evergreen or deciduous and, from a distance, reminiscent of a legume like leucaena or calliandra.

In season the tree is enshrouded in creamy white, honey-scented flowers arranged in drooping panicles 10-30 cm long. Flowers are insect pollinated and "require a large number of insect visitations," with carpenter bees the most common guests.[24] Flowers and fruits (pods) can occur twice a year; in many places flowering and fruiting occur year-round.[25] The fruits are initially light green, slim, and tender, eventually turning dark green and firm. Depending on genotype, they are up to 120 cm long. While most are straight a few are wavy and some curly. In cross-section most are rectangular but a number are triangular and some are round. Fully mature, the dried seeds are surrounded by a lightly wooded shell with three papery wings.

Distribution

Africa. Although widespread in Africa, moringa is seldom cultivated intensively and in only a few places is selected and put to use in anything like an optimal manner.

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[24] Bhattacharya1, A, and S. Mandal. 2004. Pollination, pollen germination and stigma receptivity in *Moringa oleifera* Lamk. *Grana* 43(1):48-56. The authors list pollinators as Thysanoptera (thrips), Hymenoptera, Lepidoptera, and Coleoptera, and note that delayed stigma receptivity favors cross-pollination.

[25] It is said that in the gardens of southern Florida the only tree that flowers every day of the year is moringa

Beyond Africa Moringa has long been cultivated in rural areas throughout the Indian Subcontinent as well as much of Southeast Asia. It is, for example, naturalized in Sri Lanka, India, Malaysia, and the Philippines. In addition it has been introduced to the West Indies and tropical America (from Mexico to Peru, Paraguay, and Brazil).

Horticultural Varieties

This crop has not been systematically improved, but several named cultivars with individual qualities are known in India. One called 'Bombay' has curly fruits and is considered among the best. Another, 'Jaffna,' is noted for having fruits 60–90 cm. A third, 'Chavakacheri murunga,' is known for its exceptionally elongated pods (90-120 cm long). Finally, there are the so-called baramassi varieties, which tend to flower continuously because they have been selected through the ages to provide buds, flowers, and fruits for food throughout the year. These jack-of-all-trades types are especially suitable for subsistence use. There is also a dwarf variety known as 'PKM1,' bred for the short stems that make it easy to harvest the pods, which are exceptionally long. Some Indian varieties are showing exceptional promise at the International Institute of Tropical Agriculture in Nigeria.

Environmental Requirements

Moringa is an extremely adaptable species. It grows fine throughout the warmer life zones, ranging from subtropical through tropical and from dry savanna to rainforest.

Rainfall While preferring moist situations (such as along waterways and coastal areas), it adapts to climates with several months of drought. Moringa is reported to tolerate annual precipitation of 250-1,500 mm.

Altitude Elevations below 600 m are reported best for moringa, however it thrives at elevations over 1,100 m in protected tropical uplands (southern Mexico and Dire Dawa, Ethiopia, western Kenya near Lake Victoria, for example).[26] Indeed, in some tropical areas it has been recorded growing at 2,000 m. In Ethiopia the related species *Moringa stenopetala* is regularly found at altitudes up to 1,800 m.

Low Temperature The tree is reported to tolerate light frosts without significant damage. Even when a freeze kills a mature tree back to the roots, it usually quickly sends out new growth from the ground. A good overall temperature range is 20-30ºC.

[26] In Oaxaca State, Mexico, moringa is cultivated at altitudes up to 1,200 m in sheltered locations. The highest site with abundantly flowering and fruiting moringa trees was at San Juan Gegoyache in the valley of the Totolepan River.

High Temperature No upper limit has been reported. It is known that moringa can take up to 48ºC for limited amounts of time.

Soil The tree survives on all types of soils, including the heavier clays. However, it grows best on sandy sites and alluvial lands. The soil (especially the clay ones) must be well drained because the tree is sensitive to waterlogging. It can be established in alkaline soils (up to pH 9) and acid ones (pH 4.5).

Related Species

As we've noted, out of the 13 *Moringa* species only *M. oleifera* has been accorded research and development. The rest remain almost unknown to science.[27] Perhaps they could provide even better food ingredients, flocculants, antibiotics, oils, or wood. Perhaps they have their own unique qualities. No one knows at present.

Of these ignored species, one stands out. Unequivocally African, *Moringa stenopetala* was domesticated in the East African lowlands. Many different ecotypes and cultivars are still found in Ethiopia, for instance. The plant has been called cabbage tree and it is very similar to moringa except that it is more drought tolerant and the leaves and seeds are larger. Some claim that its leaves are even tastier than moringa's.[28] In addition, this species is said to be even more promising as a coagulant for water clarification.[29] For all that, though, it is barely known to anyone but the villagers whose ancient ancestors first put it to use.

A third species, *Moringa peregrina*, is another Horn-of-Africa native. It is used as a condiment and for several other purposes in West Africa but in modern times remains almost unstudied. That was not so in the past, however. Its fruits have been found in many Egyptian tombs and it is

[27] The species are: *Moringa drouhardii* (Madagascar), *Moringa concanensis* (mostly India), *Moringa arborea* (northeastern Kenya), *Moringa hildebrandtii* (Madagascar), *Moringa oleifera* (India), *Moringa borziana* (Kenya and Somalia), *Moringa ovalifolia* (Namibia and extreme southwestern Angola), *Moringa peregrina* (Horn of Africa, Red Sea, Arabia), *Moringa longituba* (Kenya, Ethiopia, Somalia), *Moringa stenopetala* (Kenya and Ethiopia), *Moringa pygmaea* (northern Somalia), *Moringa rivae* (Kenya and Ethiopia), *Moringa ruspoliana* (Kenya). Information from Mark Olson.

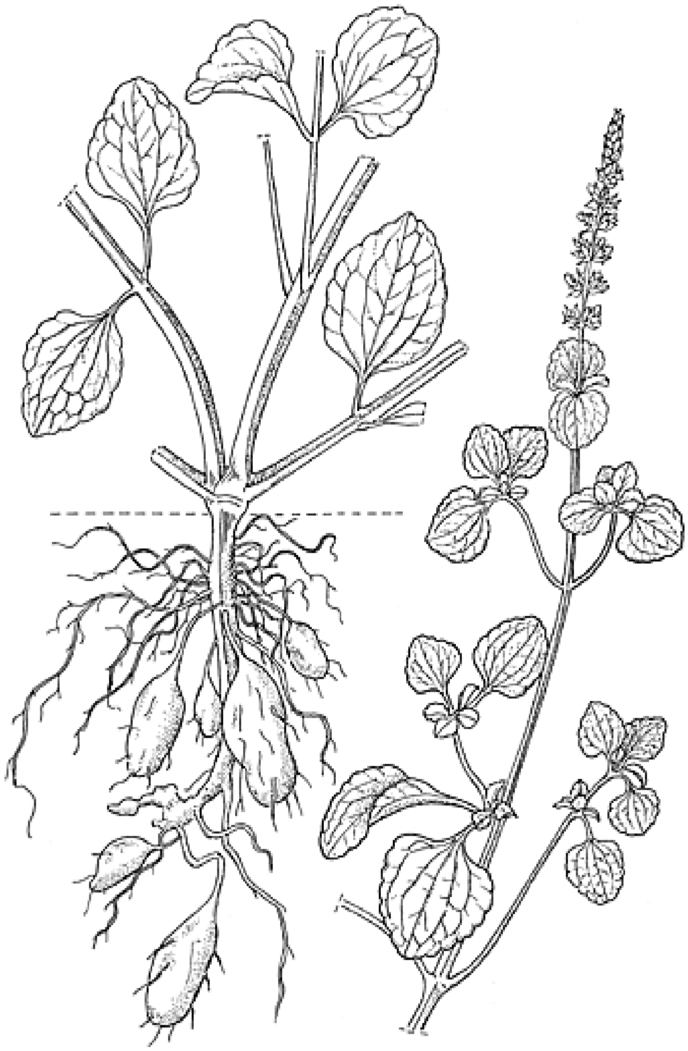
[28] Michael Madany wrote from Somalia of a comparison trial. "In spite of the initial rapid growth of *Moringa oleifera*, in drier years the species has not done well without some watering. *Moringa stenopetala*, by contrast, has the lushest foliage and continued to grow during the exceptionally long dry season from last August until this April. We began cooking leaves and young shoots in April (taste of the two species very similar). We obviously aren't eating it fast enough, since two large limbs have fallen under their own weight."

[29] The Maasai Njemps, a tribe in Kenya, use its seed to clarify the turbid water from Lake Baringo. Information from D. Odee.

frequently mentioned in ancient Egyptian texts for its oil and medicinal applications.[30] This species (a widely used synonym is *M. aptera*) provided the original ben oil (the name deriving from the Arabic *al Bân*), an odorless sweet oil that keeps well and is esteemed in perfumery. This species is still found today in Egypt and in Israel's Rift Valley as far as the southern shore of the Dead Sea. It has wood that is good for firewood and charcoal, and also reportedly resists termites.

There is also the potential for hybridizing *Moringa oleifera* with other members of its genus. *M. stenopetala*, for example, has been shown to contain flocculating agents that show a high homology to those in *M.oleifera*. With *M. stenopetala* producing bigger seeds (but usually a lower yielder) than *M .oleifera,* it may be possible to increase overall seed yield through such hybridizations. It may also be possible to increase the oil yield of *M .oleifera* by producing a hybrid with *M. peregrina*, whose seeds yield approximately 50 percent oil.

[30] Many believe the Biblical book of *Exodus* (15:23-27) is the earliest written reference to what is most likely *Moringa* being used to purify water (probably *Moringa peregrina*,): "And the people murmured against Moses, saying, What shall we drink? And he cried unto the Lord; and the Lord shewed him a tree, which when he had cast into the waters, the waters were made sweet…."



Drawing courtesy of PROTA.org

15

NATIVE POTATOES

People have eaten tubers since time immemorial. Indeed, a small but ardent band of anthropologists argues that cooked tubers in general played *the* critical role in separating humankind from the rest of the primates. According to them, the (presumably African) tubers provided foodstuffs that did not have to be chased down and required little chewing. Cooking turned the starch into sweet, appealing foods and easily absorbed calories. In addition, the tubers needed to be kept in one place under protection, so they initiated "home life." All of this—according to the proponents—prompted the evolution of large brains, smaller teeth, modern limb proportions, and even male-female bonding.

This may seem like a big indictment to pin on a few homely plants, but Harvard anthropologist Richard Wrangham and his colleagues are convinced that cooked tubers were pivotal in this way to human evolution. They don't speculate on which species led to the creation of humanity, but the subject of this chapter seems a leading possibility.[1]

Even today, Africa depends heavily on root foods. Indeed, without the contributions from cassava, potato, sweet potato, and yam, hunger would spin out of control all across the continent. Of those four cornerstones of the current food supply, however, only yam is native.[2] Yet Africa has a wealth of indigenous edible roots and tubers. Sadly, they are among the most "lost" of Africa's lost food crops.

Elsewhere in this book we describe marama and yambean, both of which are African legumes grown at least partly for tubers. Here we highlight the so-called "native potatoes," two plants grown *solely* for tubers. In culture

[1] Assuming that modern vegetation reflects what was in southern and eastern Africa almost 2 million years ago, the only other likely candidates are yam, marama, yambean, *Vigna vexillata* (a fascinating legume), and maybe tiger nut (*Cyperus esculentus*). Lesser-known possibilities from the region where humanity arose include sweetpotato relatives (*Ipomoea* species), water root (*Fockea* species), *Raphionacme burkei*, and a couple of cucurbits, *Coccinia rehmannii* and *Coccinia abyssinica*.

[2] Both cassava and sweet potato are of tropical American origin and were introduced probably in the 1600s by Portuguese slavers needing to feed masses of people crammed aboard tiny ships. Potato arrived in the African highlands relatively recently, within colonial times.

Although closely related to the *Coleus* and *Plectranthus* grown in gardens around the world, African potatoes (*Solenostemon rotundifolius* shown here) are grown for what's out of sight: tubers that can form an nutritious part of their diet. From West Africa south, tubers from different species of these edible mints have been grown for generations, but they are only now coming to the attention of scientists and development workers. (James Allermann)

and usage, these two are more akin to the conventional root crops.

Despite the name, the plants of this chapter[3] are neither potatoes nor potato relatives. Nor are they related to sweet potato, yam, or cassava. They are members of the mint family. This 3,000-member family graces human existence with numerous herbs and fragrances, including lavender, mint, spearmint, rosemary, sage, thyme, oregano, basil, and majoram, but no major root crops. Indeed, Africa's native potatoes are the only mints producing human food below ground.

Both these native potatoes are herbaceous perennials. Speaking generally, they are distributed from the warmer eastern regions of South Africa northwards to Ethiopia and from there westward as far as Senegal. The occurrences mostly overlap, however one native potato (*Solenostemon*

[3] Although this chapter deals with two species, botanists have over the centuries given different scientific names to native potatoes collected from different corners of Africa. Their taxonomic classifications depend on tiny differences in the flowers that may or may not reflect genetic differences big enough to block mutual fertility.

rotundifolius) is traditionally produced primarily in West Africa while the other (*Plectranthus esculentus*) is a resource primarily of Southern and East Africa. *S. rotundifolius* is also cultivated in parts of Asia—notably India, Sri Lanka, Malaysia, and Indonesia. Its fellow species, as far as can be ascertained, is unknown as a crop beyond Africa's shores.

Despite their age-old heritage in cultivation and cuisines, both these crops are lacking in details and certainties. The literature treats them under a (sometimes inaccurate) mix of common names. The "northern" species (*S. rotundifolius*) is most often referred to as Hausa potato, Sudan potato, Zulu round potato, fabourama, and frafra potato. The "southern" species (*P. esculentus*) is most notably referred to as Livingstone potato, Madagascar potato, and scrambled eggs.

The literature also treats them under a (sometimes inaccurate) mix of scientific names. Taxonomists peering at the flowers and other parts have accorded these plants at least a dozen different scientific epithets.[4] Some of their claims may well be valid, and there may be hundreds of species of just *Plectranthus*, but for simplicity sake (considering that our audience is made up largely of non-botanists) this chapter presents the native potato resource as if there were just two species, which is most likely the case.

Smaller than the modern commercial potato, the tubers of *S. rotundifolius* are small and oval shaped, while those of *P. esculentus* are longer and thinner, extending from the bunch at the base of the plant like fingers. The tubers of both crops are mostly boiled, but they can also be roasted, baked, or fried. Indeed, they can probably replace potato in each and every recipe—even potato salad. The flavor, at least of *P. esculentus* as served in South Africa, is described as "quite a pleasant minty taste."

As far as industrial processing goes, little is known, because the quantities produced in any one location are generally small. However, given larger production, prepared food products seem quite possible. Flour milled from dried native potato (*S. rotundifolius*, there known as fabourama) is already produced in Burkina Faso, and it is reportedly turned into popular breakfast gruels. As of now, no one has reported on what sort of French fries or chips the tubers of this ancient crop yield.

Given their Mint-Family connection, it is no coincidence that the leaves of the plant are aromatic, but the tubers are neither fragrant nor flavorful. The tubers of *P. esculentus* have the kind of blandness that is preferred in a staple. The tubers of *S. rotundifolius* are much sweeter, by comparison.

[4] These taxonomists include some of botany's biggest stars: John Gilbert Baker, George Bentham, Carl Ludwig von Blume, Nicholas Edward Brown, Auguste Jean Baptiste Chevalier, Julia Morton, Georges Samuel Perrottet, Jean Louis Marie Poiret, Anton Sprengel, and George Taylor. Among the species names they have proposed are *Plectranthus esculentus*, *P. rotundifolius*, *P. tuberosus*, *P. floribundus*, *Solenostemon rotundifolius*, *Coleus parviflorus*, *C. dazo*, *C. esculentus*, *C. tuberosus*, and *C. dysentericus* (hardly an inspiring name for a crop with a future).

Indeed, people are attracted to them for this very quality. Some liken the taste to sweet potato or parsnip. Probably in both species, however, the taste varies with locality and the individual clone of the plant. At least one observer notes that they are "an acquired taste, being rather bitter." In general, though, both tubers are well liked by both Africans and Europeans.

Currently, native potato is exclusively a smallholder crop. Indeed, it is almost exclusively a women's crop. Those who produce, collect, and process the tubers on their farms are female, both young and not so young. The tubers, overwhelmingly employed as subsistence food, make versatile family fare. They are good as a food-security insurance policy. They can, for example, be dried and put away for use during times of shortage. Although native potato is not a cash crop in the modern sense, part of the harvest is commonly put up for sale in the villages. Collectively, African women derive considerable income thereby.

Beyond the pocketbook issues, this crop is a reasonable contributor to dietary improvement. A standard serving provides a large percentage of the daily requirement of calcium and vitamin A (in the form of ß-carotene), as well as more than the daily complement of iron. The tubers contain 5-13 percent protein (calculated on a dry weight basis), or up to twice the amount found in potatoes (5 percent). In addition, the protein of *P. esculentus* is well endowed with essential amino acids (threonine, tyrosine, methionine, valine, leucine, lysine, etc.)[5] A serving thus contributes a fair portion of the daily protein requirement. The food-energy content is good as well—almost 400 calories per 100g dry matter in *S. rotundifolius* tuber.

Not only are the native potatoes nutritious, they are productive. Even in their current, horticulturally fairly primitive form, they can yield a lot of food from a small area. The recorded yields are 4 to 7 tons per hectare for *P. esculentus* and 15 tons per hectare for *S. rotundifolius*. And by employing the best plants and best cultivation practices under highly conducive conditions over 50 tons per hectare is supposedly obtainable, at least on experimental plots.

Despite these heartening signs of high production and good nutritional contributions, this is hardly a big resource in terms of geographical area or nutritional importance. Indeed, most Africans have never heard of it. Perhaps because the plants are basically hidden in plain sight no national or international research or extension organization has accorded it major support. This is unfortunate considering that calcium, vitamin A, iron, and protein—all of them vital to life—are typically deficient in rural diets in countries where this crop is found. And it is doubly unfortunate because these are big, bland staples that are eaten in bulk and can deliver quality nutrition in both a broad and a powerful manner across the society.

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[5] Allemann, J., 2002. Evaluation of *Plectranthus esculentus* N.E.Br. as a potential vegetable crop. PhD thesis, University of Pretoria, Pretoria, South Africa.

But without outside help a spontaneous adoption on a wide scale is unlikely. Working against these tuber crops is the popular impression that they are inferior, old-fashioned, outmoded foods. That impression resides in the minds of officialdom rather than of the village. It is primarily because of official (as opposed to consumer) neglect that the crop suffers from a lack of research support. And that lack is leading to sad consequences: In many locations this is another age-old resource that is dwindling toward obsolescence. And in Chad, where it is known as ngaboyo, it is said to be facing outright extinction.

Although much remains to be learned, native potatoes represent a pool of indigenous germplasm awaiting the specialists' plunge. They may never prove food-supply superstars, but they are well worth investigating. A recent report from the CGIAR declares that: "root crops will be many things to many people by 2020."[6] Driving the authors to this deduction is the root crops' adaptation to marginal environments, their vital role in promoting food security at the household level, and their flexibility in mixed farming systems. The authors note that root and tuber crops are often preferred over cereals both by farmers and consumers, and that they should be important components of programs, policies, and strategies aimed at improving the rural poor's welfare.

In this regard the native potatoes seem good candidates for pan-African attention. They are clonal crops that are easy to handle and propagate. They are found in the areas of low agricultural potential across the most needy regions of the continent. They occur where a shortage of suitable vegetable crops now results in endemic malnutrition. They produce large amounts of nutritious food from a small land area. And they seem primed for rapid advancement.

This last point may not at first be obvious. But because the native potatoes have not been subjected to intensive or extensive horticultural science, the immediate application of knowledge garnered from counterparts such as potatoes and yams—and even fellow mints—can likely bring a quick payoff. And in the long run native potatoes may have an even bigger payoff than anyone now could anticipate. Indeed, small agronomic improvements could well bring big jumps in yield. Also, more detailed research could solidify and enhance the nutritional and commercial gains to be reaped from the greater production.

Taken all round, then, these ancient native foods could prove good tools for reducing malnutrition and hunger, while improving farm profitability and providing African families with greater food security.

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[6] Scott, G.J., R. Best, M. Rosegrant, and M. Bokanga. 2000. *Roots and tubers in the global food system: A vision statement to the year 2020*. International Potato Center (CIP), Lima.

Tubers of native potatoes (here, *Plectranthus esculentus*) grow where a shortage of suitable vegetable crops now results in endemic malnutrition. They produce large amounts of nutritious food from a small land area. (James Allermann)

PROSPECTS

With these crops no one can foresee what the future holds for production or use. Not enough is known about the fundamentals to be sanguine about any future trajectory of supply and demand. The long term possibilities will become clear only as researchers burn away the mists of uncertainty and expose whatever potential is hiding behind today's doubt. But that could come quite quickly and here's what we think of the prospects for the different climatic zones.

Within Africa

Humid Areas Seemingly excellent. Tolerance to high temperature and rainfall is a feature of *S. rotundifolius*, which is widely (if thinly and irregularly) spread across Africa's tropical lowlands. *P. esculentus* prefers dryer conditions but is also in moist regions parts of South and East Africa.

Dry Areas Good but uncertain. In West Africa, to mention just one area, *S. rotundifolius* is grown from humid coastal areas to the dry interior woodlands. Nonetheless, during excessively dry periods irrigation will likely be essential to create an outcome that is commercially satisfying. *P. esculentus* produces reasonable yields in South Africa with annual rainfall as low as 450mm, although the rain must be well distributed through the season for the plants to produce under such parched conditions.

Upland Areas Uncertain, but possibly good. Native potato is generally regarded as a low-altitude crop, but some biologists have speculated that *S. rotundifolius* possibly evolved in Ethiopia. Likely, select types will be found that fit conveniently into upland habitat niches. In recent tests in South Africa *P. esculentus* has performed well at altitudes around 2000m.[7]

Beyond Africa

It is in Africa that the plants seemingly have their greatest potential, however *S. rotundifolius* is also grown in South and Southeast Asia, so there are opportunities for developing it there as well. There does not appear to be any reason why *P. esculentus* would not also be successful beyond Africa.

USES

Unlike the promising resources dealt with in other chapters, native potatoes are essentially one-product plants (omitting certain purported medicinal properties, that is).

Roots The tubers are mostly eaten as cooked vegetables. Like potatoes, they may be boiled, baked, or fried. However, one northern Nigerian type (a form of *S. rotundifolius* said to be distinguished by dark leaves) has tubers that can be eaten raw—something not even potato generally claims. The light colored tubers of *P. esculentus* in South Africa, Zimbabwe, and Zambia can also be eaten raw, and are reportedly eaten this way in Malawi too.

NUTRITION

The literature has so far provided few nutritional details from which to draw conclusions. One early report recorded a *S. rotundifolius* tuber sample as being 76 percent moisture. Its dry matter consisted of 91 percent carbohydrate, 5 percent crude protein, 4 percent fiber, 4 percent ash, and 1

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[7] James Allemann writes: "The material that I am working with was collected in the Venda region of South Africa (altitude about 850m) and has given very good results at our research station (altitude 1,164m) and in community trial at an altitude of 1,500 to 1,700m."

percent fat. The nutritional energy was 392 calories per 100g.[8]

Recent studies on the nutritional value of *P. esculentus* in South Africa recorded (on a dry-weight basis): 81 percent carbohydrate, 13.5 percent crude protein, 4 percent ash, and 1 percent fat. In addition, the tuber material contained (in mg per 100g of plant material): vitamin A (0.2), thiamin (0.04), riboflavin (0.06), vitamin B-6 (0.3), phosphorus (337), potassium (1,721), calcium (140), magnesium (327), zinc (3.5), copper (1), manganese (1.4), sodium (73), and iron (50).[9]

HORTICULTURE

This perennial is normally grown as an annual. It is, as we've said, a smallholder crop, and is probably grown in as many intercropping patterns as there are farmers. None of the cultivation methods has been investigated, but many are likely to be interesting and to reflect long-tested local experience.

Propagation is by tubers, setts, stem-cuttings, or suckers sliced from sprouted tubers. However, the standard planting method is using tubers or portions of tubers. At the beginning of the wet season these are planted into mounds, ridges, or rows on prepared beds.

Obviously, the plants need to be spaced to fit the site, the climate, and the mix of species in the plot. However, the recommended spacing varies from 50 cm to 90 cm between rows and 15 cm to 30 cm between plants. The propagation materials should, it is said, be placed (horizontally where appropriate) at a depth of 5-8 cm.

In practice, fertilizer is rarely applied, but organic material incorporated liberally into the ridges or mounds before planting, followed by a shot of fertilizer once the crop has become established, are reportedly worth the effort and expense. As in potatoes, piling earth around the base of the plants as they grow encourages greater tuber development.

Even though caterpillars of various kinds feed on the leaves, pests are rarely of economic importance. With *S. rotundifolius* weeding is said to be required only in the first stage (before the spreading foliage shades out the competing species). However, *P. esculentus* plants do not spread to such a degree, and weeds remain a problem to the end of the season.

HARVESTING AND HANDLING

Depending on the place and the plant, the tubers are ready for harvesting after 120-200 days. In the case of *S. rotundifolius* all the aerial parts have by

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[8] This sample was from the West African type called "Hausa potato." Leung, W. 1968. *Food Composition Table for Use in Africa*. FAO. U.S. Department of Health, Education, and Welfare, Bethesda, Maryland.

[9] Allemann, op. cit. Figures are in grams per 100g plant material and are measured on a dry-weight basis.

then flowered and died back. *P. esculentus*, on the other hand, does not flower at the end of the summer growing season. Instead, it drops its leaves and goes into a dormant phase during the winter. With the warmth of spring, flowers pop out of the leafless stems, after which these stems die back and new fresh growth emerges from the tubers underground. For this reason, the plant is seldom seen to flower when cultivated.

There are literature claims that the mature tubers must be dug up promptly and protected carefully—that their skin is easily damaged and they deteriorate rapidly. However, recent research in South Africa indicates that the tubers of *P. esculentus* form wound tissue extremely fast, within a few hours, so post harvest diseases are not as bad a problem as expected.[10] *S. rotundifolius* tubers have a thicker skin and are even more resistant to damage. Nonetheless, post-harvest diseases and pests can be serious. Packing the tubers in dry sand and storing them in the shade has been found to extend shelf life.

LIMITATIONS

Although pests are not normally problematic, the tubers may harbor diseases, notably including viruses and bacteria. Other clonal tuber crops commonly carry a load of such afflictions, which are passed on generation to generation. The presence of such microbes has not been shown in Africa's native potatoes; however, the possibility that they are suppressing the crop at least in parts of Africa deserves consideration.

With such a neglected resource there may well be general marketing problems to resolve in each locality, even those that know it best. The possibilities for long-distance transport, for example, are limited by the tuber's short post-harvest life as well as a lack of processing methods and storage facilities.

NEXT STEPS

Sad to say, these indigenous resources are now among the most neglected of all edible plants. Few have begun to apply modern science and given them a chance to shine. Yet, as we've noted, native potato's development seems likely to help improve nutrition and income and reduce food crises at the household level. The most immediate actions should be those oriented toward small-farmer needs. But seen in broader context, programs covering the entire chain of production, from the plant's basic scientific underpinnings through to its production and utilization on a large scale, and even government policy, are needed.

Although the full extent of their adaptability has not been tested, the plants seem likely to prove useful in hunger-fighting interventions

[10] Information from James Allemann.

throughout much of the continent. They can grow in harsh climates to which conventional staples are poorly adapted. They appear to host few economically serious pests and diseases. And the foods they yield fit well into all or most traditional cuisines, including imported ones.

There is also a need to set up a native-potato rescue program. Its goals would be to publicize the species and its potentials, to advance fundamental knowledge of the crop, and to inspire consumers and companies to use more of it. In this regard, the fate of this food could depend on a dash of marketing savvy aimed at transforming its image as being somehow inferior. Women could take an active role in shaping these efforts. That would help to ensure that they achieve additional income instead of just additional work.

The following are offered as some possibilities for specific action.

Purify the Planting Stock As noted, many of the native potatoes that farmers now plant probably suffer from chronic afflictions of viruses and bacteria, which get passed on down the generations ad infinitum. The development of tissue-culture technology in recent decades provides a powerful tool for cleaning out such hitchhiking freeloaders. In the cases of other root and tuber crops this technology has produced almost miraculous leaps in plant health and productivity. Now a government research organization in South Africa has applied it to the native potato. The Biotechnology Division of ARC-Roodeplaat has developed a program of both meristem culture and thermotherapy that eliminates viruses from the tissues.[11] ARC-Roodeplaat is already providing virus-free planting material within South Africa.

This important advance could bring far-reaching and rapid improvements continent wide. Other African nations should take note. Through contracts, collaboration, or separate efforts, they could supply their own farmers with native potato planting materials uninhibited by chronic disease. In fact, a network of pure-stock providers covering sub-Saharan Africa could be the single advance that sparks a rapid renaissance in this very old and much neglected indigenous food plant.[12]

In addition to providing virus-free germplasm, ARC-Roodeplaat maintains an in-vitro genebank containing South Africa's selected and unselected materials. For other nations this too is worth copying or collaborating. Keeping tubers viable in long-term storage is difficult if not impossible; keeping the tissues in test tubes is easy by comparison.

Survey Part of the problem with these poorly documented crops is to know just what exists. It is therefore important to collect and evaluate the

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[11] Woodward, B.R., J. Allemann, and B.P. O'Regan. 1997. Tissue culture of cassava: A South African perspective. *African J. Root Tuber Crops* 2:243-245.

[12] In fact, several networks of enthusiasts, both in Africa and abroad, are forming; the power of the Internet should allow these groups to achieve a powerful synergy.

germplasm. Also, a search for the wild progenitors would go far toward establishing the crop's genetic identity and exact place(s) of origin within Africa.

To preserve this dwindling resource's genetic diversity for future generations should be a priority. Collections should be made especially in isolated areas. The agronomic traits of the different germplasm should be characterized and important qualities noted. Disease resistance and other standard qualities are of course important. But it is the tuber qualities that are paramount: size, shape, color, flesh texture, cooking qualities, and above all taste.

Women know most about how best to produce and process this crop and their knowledge should be also collected in the dozen or more countries that employ the crop most.

Taxonomy Someone (or preferably several persons independently) should gather representative tubers from different plant types found across Africa, grow them out, and conduct cross-pollination, DNA, and other identity tests. This will determine just how many species make up the crop that in this chapter we collect under the name native potato. Cross-pollination between the species (perhaps supported by modern techniques such as embryo rescue) might perhaps lead to more robust and bigger tubered varieties due to hybrid vigor and sexual sterility. Polyploid induction, which has been successful in enlarging ginger rhizomes, is also a possibility.

Physiology Here is a plant with a possible big future and almost no scientific past. It presents plant physiologists with a clean slate waiting to be filled in. Issues to resolve in the laboratory include:

- Daylength sensitivity;
- Processes of tuberization;
- Processes of pollination; both species seem to have major sterility problems, and reportedly do not produce seed.
- Rates of growth;
- Tolerances to soil type and soil nutrients;
- Limits of temperature and altitude; and
- Water requirements.

Propagation The whole issue of propagating these crops deserves investigation. In principal, the very best means of propagating the crop for small farmers would be via stem cuttings. Those little pieces of stem are easy to collect, easy to store and transport, and easy to put in the ground. In addition, they are available in huge quantity from parts of the plant that are not edible. Although it has been reported that stem cuttings root only reluctantly, recent research found that they root fairly easily under mistbed

conditions.[13] This discovery by itself makes the crop more attractive to prospective growers.

The standard method of propagating *P. esculentus* involves planting portions of the tubers, but the effect of planting small pieces of tuber on final yields has yet to be determined.

In the case of *S. rotundifolius*, the large and medium sized tubers are eaten, and the small ones used to establish the new crop. This is a process possibly leading to the preferential selection of plants producing small tubers, a feature also needing careful investigation.

Genetics In this clonal crop seed production is rarely considered or necessary, and the plant's genetics are barely known. They should now be investigated. Efficient plant-breeding strategies can likely be devised. They will not, however, be easy…given the sterility mentioned above. If crosspollination can be achieved, varietal improvement seems likely to produce rapid advances because plant breeders can select elite types out of open-pollinated populations and then clone them for farmers.

Targets for improvement include:

- Disease resistance;
- Large tuber size;
- Smooth and regular-shaped tubers;
- Fast (and perhaps slow) maturing plants;
- Photoperiod insensitivity.

Handling Clearly, there is a need for improved harvesting, cleaning, and processing. Techniques that lower labor requirements and/or enhance value are especially required. Methods that work on other root crops will provide invaluable guidance here.

Nutrition Nutritional studies would be more than helpful, especially those that can clarify the optimum dietary mix with other foods. A notable need is to evaluate the amino acids making up the protein.

In addition, there are odd and unconfirmed reports of the young shoots and leaves being used as boiled vegetables. The literature is unclear on how widespread and safe is this practice; some mints have toxins. The broad survey of the crop's users (mentioned above) will shed light on this, but there is a need to check the possible risk and possible reward of eating the young shoots as potherbs.

Food Technology Here again, virtually everything remains to be discovered. Food technologists could have a field day pioneering the better

[13] Allemann, op.cit.

handling and processing of an unexplored tuber with the potential to help needy people. In addition, consumption could be increased in urban areas as well as rural, providing that the tuber-based products are made available in convenient forms, both fresh and processed. Required are such things as:

- Extended storage life (temperature and humidity);
- Techniques to reliably transport tubers considerable distances;
- Processing and storage at the home and village levels; and
- Commercial processing (flour, chips, or fries for instance).

An interesting possibility is that the foliage might prove useful as a flavoring or fragrance. It is now a waste product, but the fact that it comes from a relative of basil, peppermint, and the rest suggests that it might have a future in many things from soups to soaps.

Horticultural Development The most fundamental field research involves developing an understanding of just how best to produce the crops in quantity. This includes:

- Mass production of quality planting materials;
- Cultural practices;
- Plant establishment;
- Optimum plant density;
- Production under shade;
- Production in poor soils;
- Cultivation under excessively wet conditions, and also excessively dry;
- Production systems that include legumes and rotations;
- Year-round production in the hot, humid tropics;
- Reproductive pruning (removing the flowers and tops of the plants to force bigger tubers); and
- Minimum fertilizer requirements.

Intercontinental Collaboration As mentioned earlier, it is noteworthy that *S. rotundifolius* is also grown in South and Southeast Asia. Possibly, Asia's great expertise on vegetable crops might be harnessed to provide Africa with new and developed germplasm as well as new insights into handling the crop. The reverse is also possible: African specialists can provide Asia with valuable germplasm and insights of their own. Also, it may be possible to obtain expertise in tuber-crop development from South America (notably at the International Potato Center), as well as properly introducing an African tuber crop to the lands across the Atlantic.

SPECIES INFORMATION

Main Botanical Names *Plectranthus esculentus* N.E. Br. and *Solenostemon rotundifolius* (Poir.) J.K. Morton

Synonyms *Coleus esculentus*, *Coleus dazo*, *Coleus dysentericus*, *Coleus parviflorus*, *Coleus tuberosus*, *Plectranthus rotundifolius*, *Plectranthus tuberosus*, *Plectranthus floribundus* among others

Family Labiatae (Lamiaceae) Mint Family

Common Names

Afrikaans: Wilde aartappel
Burkina Faso: fabourama
Mali: fabourama
English: Livingstone potato, wild potato, country potato, Hausa potato, Madagascar potato, coleus potato, Sudan potato, scrambled eggs, Zulu round potato (*S. rotundifolius*), elongated native potato, Swedish begonia
French: Madagascar potato
Ghana: fra-fra potato
Nigeria: saluga, tumuku, Rizga (Hausa)
Chad: ngaboyo
Tswana: umbondive(ck)
Venda: Mutada, Matheta
Zulu: Umbondive, Ibonda, Ugilo, Ulucanqu, Uluhlaza, Isisqwili, Ushizane, Umhlati, ulujilo, Imbondwe, uJwangu, uShizan, uJilo, uJikwe, uHlazaluti, iZambhane
Sudan: Fa-Birama
India: koorka, koorkan, kizhangu
Indonesia: *ketang, kentang dwaja*
Malaysia: kembili, ubi kembili
Sri Lanka: innala, ratala
Malawi: buye, nyumbu, njowe, cezani
Siswati: Mlata
Shona: Shezha, Tsenga, Tensa, Tsenza
Tswana: Makwele e Sechuana
Sotho: Tapole emahlo (wild), Tapole-ea-mahlo
Xhosa: Itapile

Description

The plants are perennial herbs with prostrate or ascending habits. *Plectranthus esculentus* grows about 1 m high; *Solenostemon rotundifolius* is more prostrate and is generally under 30 cm tall. Each has a distinctive fragrant or pungent odor, due to volatile oils contained in glands or sacs in the leaves and other parts.

The stem, which is succulent and square in cross-section, is covered in white hair. The prostrate, lateral, trailing branches root at the nodes.

The leaves form in opposite pairs or whorls at intervals along the stems. They are hairy, oval, and aromatic. They can be up to 6 cm long and have toothed margins. Some plants have a central purple marking on the lamina.

S. rotundifolius flowers before the stems leaf out. In *P. esculentus* flowers are found in early spring on leafless stems. In both species they are borne on elongated, terminal racemes. Each flower is small (about 1.5 cm long) and bilaterally symmetrical with united petals, and a four-lobed ovary that produces four one-seeded nutlets. In color, they are variously reported as being violet, deep red, or yellow. Seed-set seems rare, and pollinators are unknown (though bees probably pollinated their ancestors).

The shallow, fibrous root system produces tubers that are dark brown or black in color and form in clusters around the base of the stem. Those from *S. rotundifolius* are round to ovoid and generally egglike. Those from *P. esculentus* are roughly cylindrical, up to 2 cm in diameter and 5 to 10 cm long (some as long as 25 cm have been found in south Africa).

Distribution

Possibly of Ethiopian or, more likely, later multiple origins, these and related species are now widely distributed in Africa.

Within Africa Cultivated in West, Central and southern Africa. Also reported in East Africa.

Beyond Africa South and Southeast Asia (India, Sri Lanka, Malaysia, Indonesia).

Horticultural Varieties

Basically, there are no formal varieties. However, the West African agricultural literature refers to:

- variety nigra, with small tubers and black skin, widely grown in Mali and the Upper Niger region;
- variety robra, small, red-gray or red-yellow tubers; and
- variety alba, a white-tuber variety which is also cultivated in the Upper Niger region.

Environmental Requirements

Like most else about this crop, the environmental requirements are uncertain.

Rainfall For *P. esculentus*, acceptable yields have (as already noted) been obtained with as little as 450mm. For *S. rotundifolius*, however, the minimum annual rainfall requirement is said to be approximately 1,000 mm. The plant is clearly adapted to relatively high rainfall, but it produces optimum yields only in areas where the precipitation is distributed throughout the growing period.

Altitude Limits are unreported.

Low Temperature A freeze is likely to be fatal to both crops, but in trial plots in South Africa *P. esculentus* has survived short periods of -3°C and *S. rotundifolius* -5°C.[14]

High Temperature Unknown. Temperature tolerance is a feature of many root and tuber crops although very high soil temperatures are generally damaging.

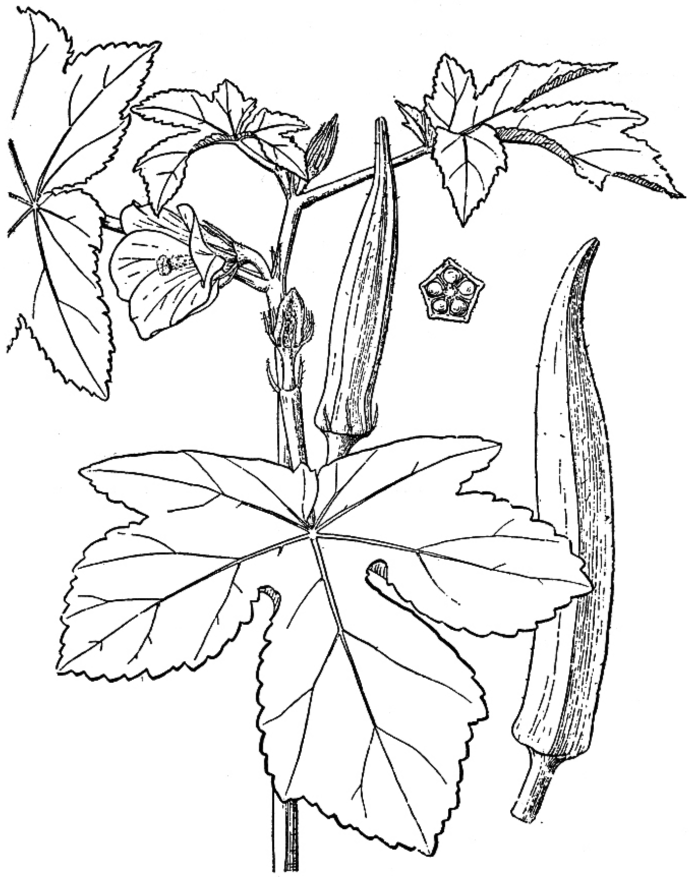
Soil Like most root crops, this one responds best in deep, well-drained sites that are well prepared before planting so that the underground portion can swell to its full size with minimal restriction. Well-drained sandy loams are preferable to clays since the crop is sensitive to waterlogging.

Daylength Sensitivity Recent work shows the South African variety is daylength sensitive with a critical photoperiod of 12.5-13 hours.[15]

[14] Allemann, ibid.
[15] Allemann, ibid.

Related Species

Several southern African wild *Plectranthus* species are also edible, with one at least regarded as a delicacy in the winter season. These extremely obscure roots have never been domesticated and probably don't warrant a formal attempt. Nonetheless, in the context of native potato research, they could perhaps provide valuable insight into such things as genetic and physiological effects.



16

OKRA

Given the fact that it already grows almost everywhere in the tropical, subtropical, and warm temperate regions, okra would seem misplaced in a book on lost crops. Furthermore, only in a few locations has it developed into a major resource. Although perhaps a hundred nations know this African species first hand, none has raised it to anything like the heights attained by, say, cabbage, carrot, or common bean in the western world. For this there seems good reason: People generally don't take to okra. In a 1974 survey made by the United States Department of Agriculture, for instance, adults named okra as one of the three vegetables they liked least, and children rated it with the four they liked second-least.[1]

The sticky, mucilaginous juice inside the pods is the main objection. That slime blinds everyone to the plant's greater potential. Of course, there are places where okra is regarded with something akin to reverence. Neither New Orleans nor West Africa, for instance, would be the same without it. But, given the crop's overall status, most observers would logically conclude that okra's natural limit as a global resource was reached long ago.

Seen in even broader perspective, however, that would be a suspect conclusion. In reality okra could have a future that will make people puzzle over why earlier generations failed to seize the opportunity before their eyes. In the Botanical Kingdom it may actually be a Cinderella, though still living on the hearth of neglect amid the ashes of scorn. Following are some reasons why it could soon rise and take a place alongside the royalty of crop plants.

This plant is perfect as a villager's crop. For one thing it is easy to grow, robust, and little affected by pests and diseases. Also, it adapts to difficult conditions and can grow well where other food plants prove unreliable. For another, it provides good yields and possibly more products than any other vegetable. For a third, it is full of nutrients. And, economically speaking, its products are within almost everyone's reach.

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[1] At least in the United States it is seldom cooked as a separate vegetable for its own sake, although there are exceptions—an okra and tomato dish in Texas, for instance, or Charleston's Limping Susan, a blend of rice and okra.

USDA Farmers Market, Washington, DC. Okra is an African market vegetable now found in cuisines as disparate as French and Japanese. It is common throughout South Asia and, of course, it is popular in Caribbean and African cooking. The word gumbo derives from a Bantu word—ki ngombo—for this vegetable. The size of a thick, long green bean, this vegetable is high in fiber and provides solid provitamin A and vitamin C, as well as minerals such as calcium, magnesium, and potassium. Okra can be boiled, blanched, fried, sauteed, and steamed and is even tasty when raw, young, and fresh. So why don't we see more of it in supermarkets and on restaurant menus? (M.R. Dafforn)

For a food resource, the okra plant is strange; it is a coarse, upright herb bearing fuzzy green pods somewhat reminiscent of beans. Their mucilage may turn off newcomers, but many Africans, and a growing number of others, consider the slithery texture no deterrent—indeed, they see it as perhaps okra's most desirable feature. A popular soup vegetable, very much appreciated in West Africa for its thickening power, okra pod is used both fresh and dried.[2] Dry pods are also pounded into flour that is commonly added to foods. In the Sahel, this flour is also used in the final stages of preparing couscous, as it prevents the granules sticking to each other.

In America, where it appears almost exclusively in stews and soups, okra is usually seen in cross section, cut into disks that look like little cartwheels with a seed nestled between each pair of spokes. Okra is also the key ingredient in gumbo, the famous dish of the American South.

[2] One study, for example, found that fresh or dried okra was the vegetable most frequently used in the Baoulé of central Côte d'Ivoire.

The plant is primarily employed, of course, as a vegetable; its pods, seeds, leaves, and shoots, as well as the outer cover of the flowers (calyx) are all eaten as boiled greens. But that is just the beginning. Okra seeds contain protein as well as oil possessing qualities like those of olive oil, the standard of excellence. And the seeds produce their protein and oil in goodly quantities. One experiment in Puerto Rico documented yields of 612 kg per hectare oil and 658 kg per hectare protein.[3] Such quantities rival those of other oil-and-protein crops of both temperate and tropical zones.

Like soybean, the seed provides excellent vegetable protein for uses including full- and fat-free meals, flours, protein concentrates and isolates, cooking oils, lecithin, and nutraceuticals (foods with functional health benefits). Okra protein is both rich in tryptophan and adequate in the sulfur-containing amino acids, a rare combination that should give it exceptional power to reduce human malnutrition. In addition, byproducts such as hulls and fiber can be used for animal feeds.

Even the "slime" might be marketable. The plant could have a future in serving the booming markets for health foods. Given an aging global population increasingly concerned over sickness prevention, mucilage is big business these days. Gums and pectins of a type comprising nearly half of each okra pod are thought to help lower serum cholesterol in the bloodstream.[4] Okra is also widely recommended as one dietary tool to help stabilize blood sugar in diabetics, because its high soluble fiber may cut the pace at which sugars are absorbed from the intestine.

The plant could have a future also as a supplier of commercial laxative ingredients. Its gelatinous substances absorb water, swell, and ensure the bulky stools that obviate and overcome constipation. Any and all dietary fiber is helpful but okra seems to rank with two crops now commanding multimillion-dollar markets: flaxseed and psyllium.[5] In other words, this vegetable may not only bind excess cholesterol and toxins but assure their quick and easy passage out of the body.

The okra plant could also provide the world with mucilage for topical use. A similar polysaccharide gum comes from aloe vera, a traditional plant exploding in use because its products are believed to help heal wounds, soothe burns, minimize frostbite damage, and perhaps provide other medicinal benefits. Despite a lack of detailed evidence, there seems no reason why okra mucilage cannot play a part in supplying industries that

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[3] Mangual-Crespo G. and F.W. Martin. 1980. Effect of spacing on seed, protein, and oil production of four okra varieties. *J Agric Univ Puerto Rico* 45:450-459.

[4] Jenkins, D.J.A., C.W.C. Kendall, A. Marchie, D.A. Faulkner, J.M.W. Wong, R. de Souza, A. Emam, T.L. Parker, E. Vidgen, E.A. Trautwein, K.G. Lapsley, R.G. Josse, L.A. Leiter, W. Singer, and P.W. Connelly. 2005. Direct comparison of a dietary portfolio of cholesterol-lowering foods with a statin in hypercholesterolemic participants. *Am J Clin Nutrition* 81(2):380-387.

[5] The ingredient in such well-known American products as Metamucil®.

now employ aloe vera. Already it is the hidden ingredient that makes catsup so hard to get out of the bottle. Okra gum is also potentially useful as an extender of serum albumin and egg whites. It has even been used to size paper in Malaysia.

This versatile plant could also have a future producing top-of-the-line paper of the sort used to make fine documents and currency. In this case, the fibers on the outside of the stalk are used. Okra has "bast fiber" like that of its close cousin kenaf (*Hibiscus cannabinus*). Both these fast-growing, look-alike African cousins open the possibility of farmers joining foresters to fill the world's insatiable demand for paper. In the United States, kenaf has already created a small industry. Kenaf is said to produce annually more paper per hectare than southern pine, the country's most productive papermaking tree. And it is harvested every five months, rather than every 30 years, which eases market planning and makes for many other efficiencies. Moreover, kenaf paper is stronger, whiter, longer lasting, more resistant to yellowing, and has better ink adherence than pine-tree paper. Although it apparently hasn't been tested yet, okra paper seems likely to be just as good.

Beyond all that, this plant could have a future also as a producer of various products used to soak up liquids. These special materials are made from the pith that remains after the stem fiber has been stripped away. In kenaf, this byproduct is proving suitable for animal bedding, for sopping up oil spills, for chicken and kitty litter, and for potting soil. It seems likely that okra's counterparts would be comparable.

Based on the rising experiences with its country cousin, okra could, at least in principle, have a future producing yet more things that are strange for a vegetable crop, including:

- Construction materials. (Kenaf-blend panels are said to perform better than the present particleboard.)
- Handicrafts. (Kenaf fiber makes excellent mats, hats, baskets, and more.)
- Forage. (Chopping up the whole kenaf plant and feeding it to animals has proven successful.)
- Fuel. (Kenaf roots and stems of burn fiercely.)

In sum, this African resource could be a tool for improving nutrition, rural life, rural development, foreign exchange, and much more.

PROSPECTS

Seen in light of the above information, okra might have a grand future as an industrial crop. And there seems to be little difficulty in producing the

Berekum market, Dormaa District, Brong Ahafo Region, Ghana. A perfect villager's vegetable, okra is robust, productive, fast growing, seldom felled by pests and diseases, and high yielding. It adapts to difficult conditions and can thrive where other food plants prove unreliable. Among its useful food products are pods, leaves, and seeds. Among its useful non-food products are mucilage, industrial fiber, and medicinals. Seen in overall perspective, this often-derided resource could be a tool for improving many facets of rural life. (Nigel Poole)

plant on a large scale. In the United States, for example, some is already produced in quantities big enough for the pods to be canned, frozen, or brined for the nation's supermarkets. As a fresh vegetable the crop's prospects are more enigmatic, but positive for all that. As with avocado or whisky, the palate's initial resistance usually mellows with greater exposure. But at core, it is an African vegetable whose greatest beneficence may well lie with its people.

Within Africa

Humid Areas Excellent. Fast-maturing types are well suited to tropical heat and humidity.

Dry Areas Excellent. Although not structurally adapted to growing under desert conditions, the plant shows remarkable tolerance to drought and heat and can generally perform reliably in Africa's savanna regions.

Upland Areas Excellent. With a crop as adaptable as this, there should be no trouble finding varieties to fit into localities up to about 1,000 m in elevation that have a reasonable growing season.

Beyond Africa

Okra is clearly not restricted to Africa. Indeed, it performs exceptionally well elsewhere. In South Asia as well as in tropical America, China, and perhaps Australia and the United States, it might well become a new agroindustrial resource.

USES

Everything part of this plant seems to offer some useful purpose or other.

Pods In their immature form the pods are the plant's main edible portion. Although mainly employed as a boiled vegetable, they can be stir-fried, battered and deep-fat fried, microwaved, steamed, baked, and grilled. Some are blanched and processed as a frozen (plain or breaded), pickled, or canned product.

Whether boiled, added to soups, or sliced and fried, the pods have a unique flavor and texture. They may be used alone or mixed with other vegetables. Mucilage released when okra slices are fried is known to be a good thickening agent for gravy. In West Africa, young pods are thinly sliced to prepare okra soup, which has been called "a perfect partner with fufu" (the region's main staple, made of starchy roots).

Inside the dried pods the gums stay intact and remain useful for flavoring and thickening foods. West Africans slice, sun dry, and grind pods into a powder that is put away for the hungry time that hits each year just before the new harvest. In Turkey the pods are strung out to dry for winter use.

Seeds Typically, the seeds are obtained from pods that become too mature to be eaten fresh. The cooked pods can also be squeezed to expel the seeds. Those seeds are commonly used in place of dried peas or beans or lentils in soups or in other dishes, including rice.

Coffee Substitute Mature dried seeds can be roasted and ground as a coffee substitute. This was once widely used in places like El Salvador and other Central American nations, Africa, and Malaysia. According to one report "the resulting 'coffee' has a good aroma and is inoffensive, since it lacks the stimulating effect of caffeine." A prominent book on African wild foods calls okra "one of the best coffee substitutes known."

Oil and Protein Okra seed's potential as a source of oil and protein has been known since at least 1920. About 40 percent of the seed kernel is oil.

This greenish-yellow liquid has a pleasant odor and a high (70 percent) content of unsaturated fatty acids, especially linoleic and oleic. It has a short shelf life but is readily hydrogenated and could be used to make margarine or shortening.

The residue left after oil extraction is a possible feedstuff. It contains over 40 percent protein as well as relatively high amounts of thiamin, niacin, and tocopherol. But some lingering questions of possible toxicity remain to be answered (see later).

Curd A research team in Puerto Rico has surprisingly found that okra can be turned into "tofu."[6] Led by Franklin Martin, the experimenters ground the seeds finely in water, strained the aqueous mixture through a cloth filter, and precipitated the protein by adding bivalent salts (such as magnesium sulfate) or acid (vinegar or lime juice). A taste panel found okra-tofu pleasant to eat fresh or cooked or as a cheese substitute. The protein and oil contents were as high as 43 and 53 percent, respectively.[7]

Leaves In areas where a wide variety of leaves are eaten (notably West Africa and Southeast Asia) tender okra leaves are often part of the daily diet. They are most frequently cooked like spinach or added to soups and stews. Some okra varieties have hairy leaves, an objectionable feature reduced by cooking; others are hairless. In West Africa the tender shoots, flower buds, and calyces are traditionally thrown into the pot as well. As with the pods, okra leaves are frequently dried in the sun, crushed, or ground to a powder, and stored for future use. In taste, they are somewhat acidic. By carefully picking lower parts of the plant it is possible to get a good crop of leaves without reducing the number of seedpods further up the stem.

Biomass At the end of the harvest season, the remaining foliage and stems can weigh 27 tons per hectare. This is quite burnable. The stems generate considerable heat but no sparks, excessive smoke, or bad smell. On the other hand, these light stems burn only briefly and to be useful may need a special stove. With fuel costs rising worldwide and new technologies promising efficient conversion to liquid fuels, okra biomass seems likely to become notably useful, especially as more tropical forests are destroyed.

Mucilage Obtaining the mucilage is simple. Slices of the immature pod are merely placed in water. Boiling thickens the mix. The mucilage is actually an acidic polysaccharide composed of galacturonic acid, rhamnose, and glucose. It achieves maximum viscosity at neutral pH, and tends to break down when overheated.

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[6] Martin, F.W. and R.M. Ruberte. 1979. *Edible Leaves of the Tropics*. Antillan College Press, Mayaguez. (3rd Edition, 1998, available via ECHONet.org.)
[7] The percentages were measured on a dry-weight basis.

Ornamental Okra is closely related to the common ornamentals known as flowering hibiscus, making okra's large and attractive blossoms seem somehow familiar (although they are yellow and sometimes come with a crimson center). The pods also have an interesting shape, and those that become too hard to eat can be dried, cured, and felicitously slipped into everlasting flower arrangements.

Medicinal Use People in the East have long used the leaves and immature fruit in poultices to relieve pain.

NUTRITION

Okra is more a diet food than staple. Pods are low in calories (scarcely 20 per 100 g cooked), practically no fat, and high in fiber. It does provide several valuable nutrients, including about 30 percent of recommended levels of vitamin C (16-20 mg), 10-20 percent folate (46-88 μg), and a little more than 5 percent vitamin A (14-20 RAE).

The leaves provide protein, calcium, iron, and vitamins A and C. No toxic substances have been reported in the leaves.

As noted earlier, the seeds are potentially a good source of an especially nutritious protein. In screening a large collection of seeds in Puerto Rico, it was found that their protein contents varied from 18-27 percent.[8] The protein's amino-acid profile differed from that of either legumes or cereal grains.[9] It was rich in tryptophan (94 mg/g N) and had an adequate content of sulfur-containing amino acids (189 mg/g N). This okra protein thus complements, balances, and fulfills that of cereal grains and legumes, not to mention root crops. One advantage to processing okra seed is its simplicity. A hand mill and sieves were all it took to separate a high protein (33 percent), high oil (32 percent) meal from the hull.[10]

HORTICULTURE

Today, almost all okra is interplanted with other crops in small farms, in backyard gardens, and sometimes in truck farms established on the fringes of cities. Only in a few places is it grown alone on large commercial fields. Most is direct seeded. Owing to the thick seedcoat, the seed is first soaked overnight to improve germination. Seedlings can also be transplanted from a

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[8] Information from F. Martin, based on Karakoltsidis, P.A. and S.M. Constantinides. 1975. Okra seeds: A new protein source. *J Agric. Food Chem* 23:1204–1207

[9] The limiting amino acids were valine, isoleucine, and lysine or threonine. P.A. Savello, F.W. Martin, and J.M. Hill. 1980. Nutritional composition of okra seed meal. *J Agric Food Chem.* 28(6):1163-6.; J.P. Cherry, personal communication.

[10] Martin and Ruberté, op.cit. These researchers also showed the usefulness of this meal in baked products.

nursery. Warm temperatures are needed both for good germination and good growth. Okra is similar to cotton in its temperature requirements. Commercial okra in the United States is planted at a population of 20,000-30,000 plants per hectare.

The crop is relatively free from pests and requires only minimal maintenance. However, in the southern United States, it can be subject to *Verticillium* and *Fusarium* wilts, and aphids, corn earworm, and stinkbugs can be major insect pests.

HARVESTING AND HANDLING

Flowering begins about 2 months after planting. Each flower then develops rapidly into a pod, which is typically harvested just 3-6 days after the flower formed. Pods harvested at this stage are tender, flavorful, and about half grown. Any that remain on the plant quickly turn fibrous and tough.

With proper field management, continuous flowering and high production can be maintained. Yields approaching 500 kg per picking per hectare (0.5 kg per plant) may be produced during a harvest period of 30-40 days. Okra is usually harvested at least three times a week. The pods have a high respiration rate and should be cooled quickly. Those in good condition will keep satisfactorily for 7 to 10 days at 7 to 10°C. A relative humidity of 90 to 95 percent helps prevent shriveling.

LIMITATIONS

The most important step in any vegetable-okra operation is harvesting the pods correctly and regularly picking the pods every few days. That induces more production and greatly increases yield.

Fresh okra pods bruise easily, blackening within a few hours. A bleaching type of injury may also develop when they are held for more than 24 hours without cooling.

Some okra plants and pods have small spines to which some people are allergic. Picking the crop can produce itchy arms.

NEXT STEPS

Of all the earth's useful plants this is one of the most misunderstood. Taken all round, it likely offers as many production possibilities as ever dreamed in a single plant. However, it also is stuck in a mental warp. Although it holds enough potential to keep a dozen researchers productive for their lifetimes, few are seriously developing it at present.

Industrial Development

With such an array of possibilities, several rural industries might be built around this species, much as around bamboo or rattan in eastern Asia. Okra

thus offers a possible route to prosperity for both small-scale and large-scale producers in numerous nations. Here are some options.

Oilseed No one knows the future okra could have as an oilseed, but at least at first sight it could be quite big. The oil is easily extracted using either solvent or mechanical press. Both the greenish-yellow color and the not unpleasant odor are easily removed. Machinery for harvesting the seed has been developed and to extract the oil machinery designed for cottonseed can be employed.

Needed now is a major follow-up to the work in Puerto Rico, which has been overlooked since it was published decades ago.[11] This should start with test plantings large enough to yield samples of okra seed oil and protein for modern evaluation by chemists, food technologists, and industries that purchase vegetable oils and proteins. It's a big undertaking, considering that okra oil and okra seed protein have never been produced in quantity before, but it could open the door to a new agroindustry for the warmer regions of the world.

Mucilage On the surface, there seems no reason why okra mucilage cannot play a part in supplying industries that now employ psyllium, flaxseed, and aloe vera. However, confirmation is needed. Issues needing clarification include the performance of okra product, safety, and likely price range. Again, growers or researchers should produce enough for evaluation by chemists, food technologists, and companies that buy mucilaginous materials. Again, it could open up the possibilities to vast new industries for many lands.

Paper Pulp Any reader who already grows okra may by now be wondering if we really know the plant. But that is only because the types grown for vegetable purposes are specially bred dwarfs, typically less than a meter in height and surely inappropriate for papermaking or fuel or particleboard. However, among this species' huge biodiversity are African varieties with stems towering 5 m and "trunks" like small trees (up to 10 cm diameter). At least in principle, those can be harvested for pods, seeds, and leaves and later felled for fiber or fuel. Some varieties even show a perennial nature. This multi-year production—like the ratooning used with sugarcane—saves the expense, trouble, and delay that comes with making a second planting.[12]

In the temperate-zone summer most of these tall, robust, West African okras bloom too late to set seed. Instead, they devote their considerable energy to vegetative growth. Far surpassing garden varieties in the

[11] Martin and Ruberté, op.cit.

[12] As far back as 1979, J. L. Siemonsma described two distinct types of okra from Côte d'Ivoire, and brought the existence of almost perennial races to attention.

production of fiber and biomass, they have the potential to revitalize okra breeding and okra as a global resource.

These tall types should be obtained and put into worldwide trials. Some trials should involve side-by-side comparisons with kenaf.

Bioabsorbents Pith, as we've said, comprises a major part of the stem. In kenaf it is proving suitable for animal bedding, oil-absorbents, chicken litter, kitty litter, and potting soil. Okra pith samples should be gathered and compared with kenaf's. For these purposes, the two crops are less in competition than in cohoots. They can undoubtedly be marketed together and perhaps even mixed, thereby building a bigger, broader, and safer base of supply. Demand for bioabsorbents like these is likely to soar, both for the needs of environmental health and public health around the globe.

Horticultural Development Although there has been considerable selection and breeding of okra, it has emphasized the production of immature pods. The rest of the fantastic genetic diversity within this species is basically untapped, or even unexplored. That situation should be changed, and fast. Germplasm needs to be gathered up not only in Africa but also in Asia and other regions that know the crop.

With this genetic variability in hand, the way should be open for improving the compositional value of the crop for the various separate products. Varieties could be bred, for instance, for fiber, biomass, oil, protein, mucilage (type and yield), color, and ornamental use. Breeding studies could also be expanded to include improving yields, cultivation conditions, nutritional value, and nutraceuticals.

Okra flowers are structured for insect-pollination (bees, wasps, flies, and beetles, and perhaps even occasional birds), but self-pollination usually occurs and both hand-pollination and seed handling are straightforward. Controlled breeding is thus not difficult, although success in bringing out some characteristics may require very large populations and very careful evaluation.

Toxicity Checks Although both okra tofu and the protein-rich residue left after oil extraction offer promising foods and feeds, there is a possible drawback. Okra seeds, like cottonseeds, purportedly contain gossypol or a gossypol-like compound.[13] All doubts will have to be removed before okraseed can be employed as a protein source. Strangely, should gossypol be present in commercial amounts it might possibly be used for the long-sought male contraceptive (see sidebar).

In at least some okraseed varieties the oil contains small quantities of cyclopropenoid fatty acids. These unstable compounds have strong

[13] Gossypol occurs also in cottonseed oil, from which it is extracted with butanol.

physiological effects and in hens are believed to suppress egg laying. However, the fact that some okra plants had only low quantities (the overall range was 0.26-5.59 percent) suggests that the problem might be bred out. These unusual fatty acids are easily removed by heating the oil during processing, but having none to start with would surely be better.

Basic Studies There are undoubtedly many fascinating physiologic and genetic features of the plant to investigate. Here are three that come to mind:

- *Ploidy* Okra has a high number of chromosomes (2n=130) and behaves in some instances as a diploid and in others as a tetraploid. It is thought that one genome possibly comes from *Abelmoschus tuberculatus* (2n=58). Modern techniques could likely go far in sorting out okra's genetic background and chromosome make up.
- *Hybridization* Crossings within the species as well as possible hybrids with okra's close, interesting, and useful relatives ambrette (*Abelmoschus moschatus*), kenaf, and roselle (*Hibiscus sabdariffa*) could provide fascinating plants with exceptional properties.
- *Okra's origin* Many publications still give the species' origin as India, but that seems more current usage than scientific assessment. The vast occurrence of primitive types and wild relatives in Africa (especially Ethiopia) indicates okra is almost certainly African, but the lingering doubt should be put to rest by groundwork and DNA testing.

Food Technology

Here, too, are possibilities for fascinating research. Examples include:

- *Okra Tea* Okra's close cousin roselle has been making a name for itself in recent years as a major ingredient in non-caffeinated teas (notably in the United States, where it stars in the popular Red Zinger Tea®). Jamaicans know this okra relative as sorrel and consider it one of the island's great delicacies, turning it not only into cooling beverages but into famous tarts and jellies as well. It is also a common tea in the Sahel, where it was introduced to provide plant fiber and vitamin C, and has now naturalized. Okras with red calyxes are known and should be tested for the possibility of producing a counterpart.
- *Decaffeinated Coffee* Could okra seed be a direct route to a really good caffeine-free beverage? That is something for which a market seems more promising now than ever before, and the possibility deserves at least a look-see.
- *Gum-Free Okra* Needed also is a simple test for mucilage content that would allow the germplasm to be screened. Then, pods of known polysaccharide content could be bred. Anyone creating gum-free okra will have given the world a major new crop. Of course, anyone creating

exceptionally gum-rich okra will also give the world a major new crop.

Progress and Public Relations In spite of the fact that okra is a potentially very important plant, little effort is being given to its development. As noted, this is largely due to the public's negative mindset. To overcome popular repugnance requires more than science…it requires publicity. Some sort of Okra Appreciation Society would help give the vegetable a good push. It might foster newspaper and magazine coverage of okra's possibilities. And it might operate such things as contests, recipes, home-economics courses, and nutritional awareness demonstrations. Although the plant's prospects are high, its future depends on a mental course change to break it out of the slime still blinding everyone to the crop's greater potential.

SPECIES INFORMATION

Botanical Name *Abelmoschus esculentus* (L.) Moench

Synonym *Hibiscus esculentus* L.

Family Malvaceae

Common Names

Arabic: bamia, bamya, bamieh
English: okro, lady's finger, ladies finger, gumbo
India: bhindi, bindi, dheras, bandakai, vendakai
Chinese: ka fei huang kui, huang su kui, huang qiu kui, qiu kui (medicinal name); chan qie, ch'aan k'e, Ts'au kw'ai (Cantonese)
French: gombo, bamie-okra, ketmie comestible, ambrette
German: ocker
Spanish: gombo, ají turco, quimbombo, ocra
Portuguese: gumbro, quingombo, quiabo, quillobo
Akan (Twi): nkruman, nkruma (okra)
Bantu: ki ngombo, ngumbo, gombo
Congo, Angola: quillobo, ki ngombo
Swahili: gumbo
Thai: krachiap khieo, krachiap mon, bakhua mun
Greek: bamia
Hebrew: bamiya, hibiscus ne'echal
Hungarian: gombó, bámia
Italian: gombo, ocra, bammia d'egitto, corna di greci
Japanese: okura, Amerika neri, kiku kimo
Malaysia: bendi, kacang bendi, kacang lender, sayur bendi , kacang lendir , kachang bendi
Indonesia: kopi arab.

Description

Okra is an annual herb typically reaching 2 m in height, but some African varieties may grow up to 5 m tall, with a base stem of 10 cm in diameter.

The heart-shaped, lobed leaves have long stems and are attached to the thick woody stem. They may reach 30 cm in length and are generally hairy. Flowers are borne singly in the leaf axils and are usually yellow with a dark red or purple base. Some African varieties are photoperiod sensitive and bloom only in the late fall in temperate zones. It is largely to wholly self-pollinated, though some out-crossing is reported and it is often visited by bees.

The pod (capsule, or fruit) is 10-25 centimeters long (shorter in the dwarf varieties). Generally, it is ribbed or round, and varying in color from yellow to red to green. It is pointed at the apex, hairy at the base, and tapered toward the tip. It contains numerous oval seeds that are about the size of peppercorns, white when immature and dark green to gray-black when mature.

Distribution

The plant is immensely adaptable and is widely distributed in the tropics, subtropics, and warmer temperate zones. In essence, it grows almost everywhere anyone tries to plant it.

Within Africa Of all the native food crops, this is one of the most widespread within the continent. It is known from Mauritania to Mauritius, with most diversity centered around Ethiopia and the Sudan.

Beyond Africa It is now grown throughout southern Europe, Australasia, tropical Asia and America, the Caribbean, and the United States, where it is best known in the southern region but is also cultivated in Oregon and California. Turkey grows okra on a large scale.

Horticultural Varieties

Many cultivars have been selected for local conditions but in the main there are two types: the long and the short (quickly flowering) duration. The cultivars vary in plant height and in shape and color of the pod. With all the different cultivars and their variations, the particular kind of okra planted usually reflects what the local people prefer their dinner dishes to look like.

Although okra prefers a long, hot growing season, cultivars have been developed that are short in stature as well as fast maturing, and small fruited. These dwarf, short-duration types reach a height of 60 cm and require only 7 to 9 weeks to mature.

The okra seen in the temperate zones is fairly uniform. One survey of

266 temperate-zone varieties found no consistent differences. But that is misleading; this species encompasses huge genetic diversity that not even okra specialists have ever seen—it just hasn't been distributed in the temperate zones.

Environmental Requirements

Okra is a warm-season annual well-adapted to many soils and climates.

Rainfall The plant tolerates a wide variation in rainfall.

Altitude Most selections are adapted to the lowland humid tropics, ranging up to at least 1,000m.

Low Temperature Minimum soil temperature for germination is 16°C. For good growth, night temperatures should not fall below 13°C.

High Temperature An average temperature of 20-30°C is appropriate for growth, flowering, and pod development. Most cultivars are adapted to consistently high temperatures.

Soil A range of soil types give good economic yields but (not unexpectedly) well-drained, fertile substrates with adequate organic material and reserves of the major elements are ideal. Some cultivars are sensitive to excessive soil moisture, so well-drained, sandy locations are preferred. Neutral to slightly alkaline conditions, pH 6.5-7.5, seem best.

Related Species

The genus *Abelmoschus* includes from 6 to 15 species in the Afro-Asian tropics and North Australia. One that stands out is abelmosk or ambrette (*Abelmoschus moschatus* Medik.; syn. *Hibiscus abelmoschus*). Indigenous to India and cultivated (or weedy) in most warm regions of the globe, it is a low, slightly woody plant with a conical five-ridged pod containing numerous brown kidney-shaped seeds that are smaller than okra's. The seeds possess a musky odor and perfumers know them as ambrette ("abelmoschus" is from the Arabic "father of musk", with "moschatus" also referring to a musky smell). The plant also yields an excellent fiber and, rich in mucilage, is employed in upper India for clarifying sugar. One variety there known as bendi-kai is eaten fresh, prepared like asparagus, or pickled. The foliage and tubers of *A.m.* subsp. *tuberosus* have been consumed for centuries in Australia.

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SHEA

Shea may not be well known in a global sense, but it certainly is well known in West Africa. There, it constitutes the principal useful tree in a band of savanna nearly a thousand kilometers long. Traditionally, this large and treasured species, not unlike oak in general appearance, provided the primary edible vegetable fat to peoples inhabiting an estimated 1 million km^2 of wooded grassland. Early travelers observed that the cultures in that vast area—which collectively extends through 13 of today's countries, from Senegal to Sudan and Uganda—revolved around shea.[1] One such traveler was Ibn Batuta, who passed through in 1348; another was Mungo Park, the first European to trace the inland flow of the Niger River, in 1796.

Although few outsiders have heard of it, shea (pronounced "shay" or "shee") remains among West Africa's most extensive resources. All told, an estimated 500 million specimens of fruiting age exist, which probably equals the number of almond trees worldwide. The tree's fruits resemble large plums or very small avocados. The smooth-skinned, egg-shaped nut found at their center contains a kernel that yields the fat, which is widely used for cooking or for food. Indeed, West Africans use it much like Westerners use lard and butter.

This lipid is not liquid like a common vegetable oil. Rather, it is solid. Even in the tropical heat its texture ranges from a creamy paste to something like firm butter. A well-made sample taken from fresh nuts is white, odorless, and nearly tasteless.

It is difficult to overstate this vegetable fat's importance to the inhabitants of the semiarid zone below the Sahara. For millions living in this harsh location, where food is difficult to produce and life hard to sustain, shea butter is vital to everyday existence. It enhances the taste, texture, and digestibility of the major regional dishes. It is, for example, added to the staple known as tô—mainly to prevent that pasty porridge's surface from drying out but also to add flavor and consistency. Shea butter is also used when frying fritters, griddlecakes, and many other foods for use in the home or for sale in the markets.

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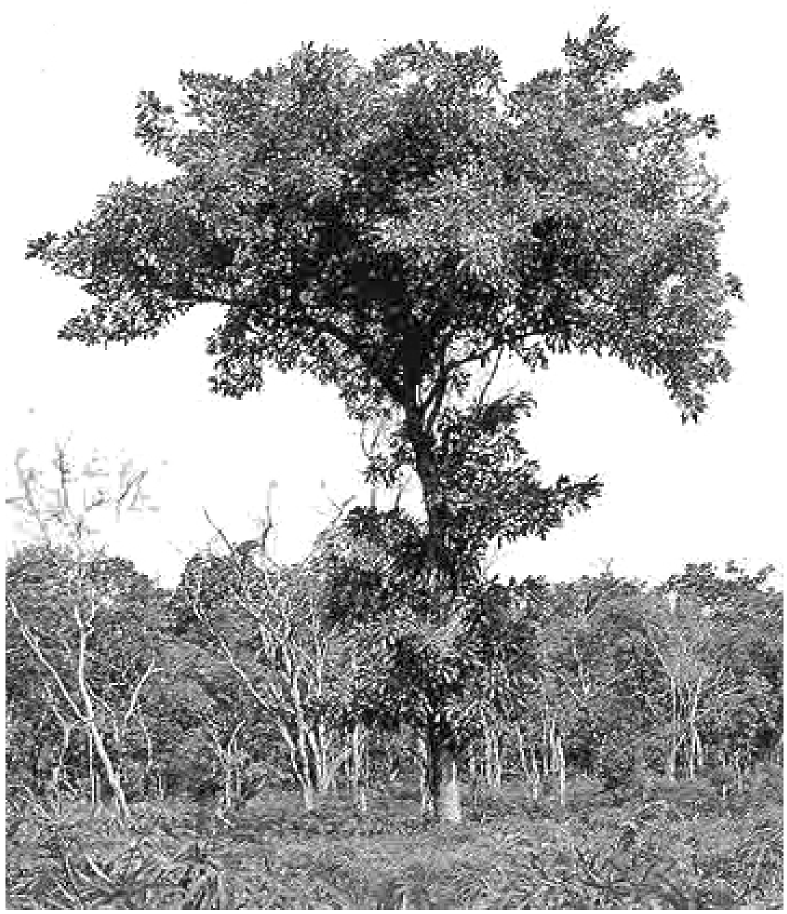
[1] Cultures historically reliant on shea include the Bambara, Fulani, Hausa, Mandingo, and Mossi (Burkina Faso's largest ethnic group).



Traditionally, the large and treasured shea butter tree provided the primary edible vegetable fat to peoples inhabiting a vast tract of wooded grassland this is vulnerable to some of the worst droughts of the arable world. It is often the only tree allowed to grow through its allotted lifespan, 400 years or more. Nutritionally speaking, shea is noteworthy for providing storable food that is capable of providing a steady source of buttery energy year-round. (E,C.M. Fernandes, ecf3@cornell.edu)

Beyond shea butter, this tree produces edible fruits, edible flowers, medicines, and several other necessities. And it does it all without human help or horticultural support in some of the most challenging inhabited sites on earth.

For all its international obscurity, shea is clearly very important. It is often the principal economic resource over extensive areas where little else saleable can be found or grown. It is the main profit center for the poor.

Throughout the Sahel, shea provides poor people cash. A survey in Burkina Faso indicated that the nuts provide 20 percent of family income, a figure that can be taken as generally representative of several neighboring nations and parts of nations. The Sahelian countries can hardly be called prosperous, of course, but without shea they would be much poorer. In Mali, field studies indicate that in areas where the shea is widespread 90 percent of the households engage in its processing, and that shea products contribute up to 60 percent of women's income. In years of poor production local market activity in notably affected.

Women are the ones who collect shea nuts. Women also extract shea butter. And women selling the butter in local markets are a commonplace sight. According to estimates, the tree provides more than half women's income in the rural Sahel. An observer has estimated that these nuts provide income to more than 2 million women, which is in all likelihood an underestimation.[2]

This tree also provides the Sahel with foreign exchange. Both the seed kernels and the butter are shipped to Europe and Japan, and now the United States, where they are processed into baking fat, margarine, cocoa-butter substitutes, and various beauty aids. Such exports have a long history. In Cleopatra's time, for instance, caravans bore clay jars of shea butter across the Sahara to Egypt where it was used in cosmetics, probably including those the queen herself applied. Since at least those dynastic days, shea exports have been providing West Africa with revenue. Currently Burkina Faso and Mali, which together ship over 100,000 tons of dried kernels annually, are the principal exporters. But shea is also an important Ghanaian export. Indeed, it's Ghana's third ranking cash crop; only cocoa and coffee exceed it in foreign exchange earnings. It is Burkina Faso's third largest export as well.

Although renowned for the food it provides, this tree's non-food products are valuable too. Across West Africa, shea butter is applied to the skin and hair. Refined in modern factories, it is incorporated into soaps, ointments, and skincare products of numerous kinds. It is also used to waterproof the walls of houses, so as to stop the infrequent downpours from washing the mud away. Furthermore, it is a staple of West African medicine. For thousands of years local healers have used the pasty solid to protect small wounds, heal infections, and soothe the aches of sprains and strains. Moreover, they prescribe it as a decongestant and an arthritis treatment.

People are not shea's only beneficiaries. This tree's environmental contributions are hard to overstate. For one thing, shea and locust (Chapter 11) commonly provide the only tree-cover across an area that is vulnerable to desertification. (the main zone of areas threatened with desertification is

[2] Hyman, E.L. 1991. A comparison of labor-saving technologies for processing shea nut butter in Mali. *World Development* 19(9):1247–1268.

north of where the shea is principally found; however, shea is primarily responsible for helping to prevent wind erosion and adding organic matter back to the soil). Its importance in this regard is locally understood. Laws forbid anyone from destroying a shea, and in most West African countries a person found felling one is prosecuted. As a result, shea trees are traditionally preserved during land clearing and farmers guard and tend the existing specimens, many of which are privately owned.

Perhaps it is no wonder this single species ends up forming pure stands often hundreds of hectares in extent. But beyond the solicitude of people and governments lies a probably more important reason: the thick and spongy bark. This covering is fireproof and it protects shea trees from the periodic blazes that incinerate other species.

Because of these natural and manmade protections much of the grassland below the Sahel is more like grassy woodland.[3] Shea turns it into a sort of park, commonly with as many as 20 to 25 mature trees per hectare savanna. Moreover, much of it is a farmed park and is in fact a creation of human selective pressure over generations. Shea are protected and other species culled out. This is one of the most widespread and striking examples of traditional agroforestry associations found anywhere on the planet. People plant their crops among the trees. Shea combines well with cereals; farmers usually protect their trees with great care. Even though anything casting shade on a crop reduces yields, research indicates that in the short run the value of shea products more than compensates for the lost production, while in the long run the soil-saving services conferred through the trees presence may far exceed any yield losses. This time-honored farm/park landscape covering major portions of the Sahel is a perfect example of large-scale agroforestry. The dispersed trees form an integral part of the normal cropping system and have done so for centuries, if not millennia.

A self-reliant tree species that provides food in the dry, drought-seared savanna would seem the ultimate in sustainable agriculture. Making the most of the difficult climate and the most of the largely worn-out soil, the trees need no care and may live several centuries.

But these upbeat points constitute only one side of the shea story. Based on its benefits shea may seem exceptionally promising, but that does not mean that overnight it can turn into a miraculous new resource. For this, there are several counterbalancing and discouraging reasons.

First, it is far from easy to build a bigger and better shea industry because the current trees are all wild. As a result, they are widely scattered and their yields vary up and down from year to year. A steady harvest can therefore never be relied on.

Second, this species has so far proven recalcitrant to research. It has been

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[3] In the true Sahelian zone (200-600 mm rainfall), few shea are found. The classic 'shea parkland is found further to the south, beginning in the northern Guinean zone and peaking in the Soudanian zone.

called temperamental and awkward and has only recently, for instance, been brought into plantations like oil palm or olive. Indeed, getting the shea tree to the point of formal cultivation presents so many challenges that both mainstream science and modern industry have largely passed it by.

Over the last 50 or so years there have been sporadic attempts to establish plantations, but in the past none was ever followed through to a successful conclusion. Indeed, only now do they seem commercially promising. For that, there is a simple explanation: The trees are very slow to mature. Moreover, the search continues for regular-fruiting varieties that can be relied on to yield fruit consistently year after year. It is little wonder, therefore, that many researchers basically gave up on this species. Most concluded that large-scale plantings would never be viable. In their frustration, they dubbed the shea tree “untamable.”

Third, the production of shea butter remains mostly a cottage industry, which restricts its size and reliability. Worse, it is a process so onerous that to produce a liter of butter requires eight hours of very hard labor. Indeed, it takes so much time it must be put off until the dry season when not even farm chores can interfere.

The traditional process as used by Sahelian women is especially tedious. During the month or two in which the fruits are ripening, they visit the trees almost daily to collect any fallen ones before others or animals get to them. They set the fruits aside to ferment. Once the pulp has rotted a bit and the seed inside has separated, they remove the seed, wash it, and usually lay it in the sun to dry. Alternately, some seeds are dried, either by a briefly roasting in an oven or boiling followed by sun drying. Once they’ve been heated and dried this way, the seeds can be safely stored. They are also easily shelled to release the kernels inside. In the main processing step, those kernels are crushed or finely ground and heated once more. The resulting hot brownish mash is then churned and strained and kneaded for hours until the white pasty fat emerges.

This lengthy and exceedingly tiresome operation is done almost all by hand. Processing shea seeds is so laborious as to almost defy economic sense. Furthermore, poverty often compels women to sell their shea products to agents who then sell them on to exporters, who in turn sell them to the international food or cosmetic industry. The women—without whom shea products would be unavailable—thus profit little from their weeks of hard labor. One estimate of the maximum value of shea butter production per family per year was US$35. Even as grower cooperatives show increasing promise, old marketing patterns remain difficult to overcome

In sum, then, the shea tree is an enigma.

And the trends in modern times are making it ever more enigmatic. Following this long period of research neglect, consumers worldwide are discovering shea products for the first time and are demanding more. For one thing, food industries are finding special uses for shea butter in pastries

Although few outsiders have heard of it, shea (*Vitellaria paradoxa*) remains among West Africa's most extensive food sources. West Africans use its smooth-skinned, egg-shaped nut much like Westerners use lard and butter. For a vegetable lipid this one is unusual in that it remains solid even in a tropical climate. Countless Africans also use this so-called shea butter for skincare, and these days the product is going global and going upscale in some of the most expensive cosmetics ever formulated. High quality traditional shea butter sells for $0.75/kg in this Yendi, Ghana market (2003); shea butter produced by traditional methods is available online for $17/kg to more than $400/kg for the very highest quality material. (Peter Lovett)

(where it provides high dough pliability) and confectioneries (where it acts as a substitute for cocoa butter). Shea butter is also becoming a worldwide base for cosmetics and for treating such things as dry hair, dry skin, burns, and general dermatological ailments. The Internet is already overpopulated with peddlers pushing this newest skincare wonder.

Clearly then something needs to be done about this crop. Not only is the international demand rising, but the people living where shea grows are among the poorest and most desperate on earth. Any product capable of earning them an income and earning their countries foreign exchange is a critical resource.

Thus, despite abandonment by previous researchers and claims that the tree is untamable, action to advance shea production must be renewed. And it is finally happening. Some development agencies and many NGOs, focusing especially on women's issues, have initiated innovative programs. Some seem to be showing great promise, but scientifically almost everything remains to be done. Though shea butter (of highly variable quality) is appearing in many products worldwide, especially cosmetics and balms, no one—least of all the present writers—has a full grasp on exactly what all to do.

As noted, in the past few years the importance and potential of shea has drawn the attention of several government and nongovernment organizations, as well as commercial enterprises—especially as shea butter has become a premium ingredient in skin emolients. Appropriately, much of this work has been developmental rather than research; the journey is just beginning toward understanding this outstanding plant. In the Next Steps section below, we present some possible lines of investigation that could lay the foundation of a greater, more reliable, and more profitable resource—one that helps the people and the land, both of which are among the most defenseless on earth.

PROSPECTS

A holdover from the ancient times, shea butter is a still-unbroken link between the hunter-gatherer and agricultural civilization. But whether it finds an even greater place in the 21st century will still depend on raising and regularizing its production. How, when, and where shea will end is therefore more guesswork than judgment. It is even possible that shea will achieve a lesser place in this new century. The trees are being subjected to pressure from agriculture, drought, and a parasitic plant that sucks out their lifeblood. Shea butter production may actually decline in coming years. On the other hand, the prospects for greater production should rise as applications in the cosmetic and pharmaceutical industry develop. That would make shea butter commercially more desirable and it would not only give more cash to the producers but also more incentives for even greater development.

Within Africa

Humid Areas Probably poor. Shea is not known in locations where rainfall and humidity are high…but the reason behind that is not known either. Although the tree might possibly thrive under good rainfall, it seems unlikely that it would be a viable resource in any location where oil palm, other oilseeds, or cacao grow well.

Dry Areas Fair to good. This is the climatic zone where the tree finds its greatest prospects of course. Any tree that can provide resources in this hot, dry, exasperating locale would be welcomed. In this case, though, it is only in the dry areas of West Africa that it holds reasonable commercial promise. Parched locations in East and Southern Africa should try another crop if they want any commerce to eventuate.

Upland Areas Poor or limited. Shea grows at an altitude of 1,200 m in Cameroon, but most African highlands can find more reliable alternatives for producing the kind of products this tree yields.

Beyond Africa

Commercially speaking, shea is probably not yet worth trying. Even if it will grow well in a non-African setting, the combination of matching the climate, long lead-times for production, and processing challenges may keep shea at a competitive disadvantage outside Africa.

USES

The nuts and the butter tend to be used for different purposes when exported than when used locally. In Europe, for example, the fat is prepared by mechanical means and is used as a cooking fat, as a raw material for manufacturing margarine, and as a substitute for cacao butter in such things as chocolate and cocoa and used in cosmetics. The press cake or extracted meal ends up as cattle feed.

Below, we highlight the age-old West African uses.

Fruits The sweet, yellow or green pulp of the fruits is eaten when fresh. It is not unlike avocado and provides a valuable food during the early part of the rainy season, a time when other eatables are often scarce. Each tree typically produces 15 to 20 kg of fruit.

Seeds The kernel found within the walnut-like seed (that lies at the heart of the fruit) is, as we've said, the tree's major product. The kernels can be eaten fresh or roasted like almonds. The typical shea tree's annual yield of 15 to 20 kg of fruit corresponds to 3 to 4 kg of kernels or 1.5 to 2 kg of fat.

But the traditional methods of extraction recover only about half that. In other words, 4 kg of kernels generally yield less than 1 kg of shea butter.

Flowers The outer whorl of sepals (the calyx) is edible and is eaten especially in salads.

Shade The shea's spreading crown is much appreciated for the coolness it throws. In the torrid locations where this tree grows, people and animals both cherish its shade above almost everything else.

Wood The wood is hard and red in color. It reputedly resists termites, and finds various applications as a utility timber. For one thing, the wood is renowned for making tools. For another, it is used for coffins. In fact, it was the traditional material for ancient kings' funeral beds, carved from the wood of a noble old shea tree—a fact indicative of just how intimate and long the relationship between humans and shea has been. The wood makes good charcoal and fuel as well, although, because of its high value as a food, the tree is not felled for burning, even where fuel is in high demand.[4]

Cosmetic Uses Countless Africans use shea butter for cosmetic purposes, and these days the product is going global. Indeed, it is touted on the Internet as the only moisturizer or emollient a person could ever need. It has a mild, pleasant smell and combines well with essential oils for any desired fragrance. According to the breathless advertising, shea butter is the ideal treatment for dry, damaged, or aging skin and hair. Proof is lacking, but the possibility this is the truth seems real to users.

Medicinal Uses As noted, shea butter is locally used in medicines. It is particularly valued in ointments for boils and skin diseases. Despite a dearth of controlled experiments, it seems to enhance the healing of small wounds, cracks, crevices, and ulcers in the skin. Reportedly it contains no known allergens and is used even around the eyes. The tree's roots and bark have separate medicinal applications, which are less well documented or trustworthy. In addition, the wastewater from processing kernels is often used as a pesticide against weevils, apparently with good effect.

Other Uses Shea butter is said to be "the ideal treatment for drumheads." In addition, the leaves and young sprouts serve as forage. Although the foliage's palatability is said to vary greatly with the tree and the location, livestock generally like it. Sheep and pigs also eat the sugary pulp of any fruits that have fallen to the ground. The flowers yield nectar for bees. As

[4] This is true even around Ouagadougou and Bamako, the capitals of Burkina Faso and Mali, for example. There, you see the trees standing full and tall.

Fresh fruits, fresh nuts, and dried shea kernels in Tenkodogo, Burkina Faso. "Shea butter" is extracted from the kernel, which contains 50 percent fat. It is an essential source of nutrition and cash for many families. Collected, processed, and marketed exclusively by women, shea is frequently their primary source of income and central to household security in homes from Senegal to Sudan. Today, exports for fine cosmetics and other value-added products are climbing rapidly and approach 10 percent of total production, which is around 600,000 t/yr. Development efforts are underway at many levels—from local cooperatives to United Nations' affiliates—to reinforce the vital economic links that shea creates among sustainable production, local labor, and export earnings. (Marlène Elias/Globalization-Africa.org.)

mentioned earlier, shea butter is daubed to waterproof mud walls. Most often, a coat of the fat is applied seasonally around the dwelling's doors and windows as well as along the base of the outer walls.

NUTRITION

Nutritionally speaking, this tree is noteworthy for providing a storable food that can provide a steady source of dietary energy year-round. Shea butter is made up mainly of triglycerides. Two fatty acids predominate: oleic (unsaturated) and stearic (saturated). The average fatty-acid composition has been given as: oleic, 40 to 55 percent; stearic, 35 to 45 percent; palmitic, 3 to 7 percent; linoleic, 3 to 8 percent; and linolenic, 1 percent.

Whereas the fatty-acid composition of shea and cocoa butter are fairly similar, shea butter has a much higher content of unsaponifiable matter, up to 17 percent unsaponifiables (8 percent on average). This non-fat fraction is composed of phenols: tocopherols, triterpenes (alpha-amyrin, lupeol, butyrospermol, parkeol), steroids (campesterol, stigmasterol, beta-sitosterol, alpha-spinasterol, delta-7-avenasterol), and hydrocarbons (2-3 percent karitene). It also contains terpenic alcohols.

HORTICULTURE

Strictly speaking, there is no such thing as shea horticulture. After all, there are no operating plantations. However, where people have tried planting the trees they have commonly employed a regular grid pattern with 10m x 10m spacing.

Shea seeds germinate easily when fresh but lose this ability quickly. The seedlings grow a long taproot, which endows great drought resistance, but makes them difficult to transplant. Seeds are therefore perhaps best planted *in situ*. Trees raised from seed mature very slowly, bearing their first fruits after 12-25 years and taking 30-50 years to achieve full productivity.

In principle, vegetative propagation could reduce that delay and lift the crop's potential in many other ways. So far, though, it has not been accomplished on any scale. This is an exciting time in shea propagation. Success with cuttings has been achieved, though methods presently seem challenging except with good skills and facilities. Grafting, though difficult and often inefficient, also works if practiced carefully. Air-layering has also been successful, yet it too has proven difficult to pull off reliably in practice. *In vitro* propagation is also reported. Just which methods to recommend are uncertain as of now; practitioners and decision-makers are advised to start first by searching the Internet and then consulting experts before making any long-term commitments.

In the wild, the tree sends up root suckers, a propensity probably providing the easiest way to produce shea vegetatively for small-scale commercial purposes. One researcher has recommended laying root sections (about 15 cm long and up to 1 cm thick) in nursery beds or large pots. After about two years, the resulting plants can be moved into the field. Although slow, this procedure is free to the local grower, and may remain the best method to increase planting material until elite selections become more widely available and reasonably priced.

Shea suffers from few diseases but some insect pests and four parasitic mistletoes (*Tapinanthus* sp.) cause it great—even mortal—damage.

HARVESTING AND HANDLING

The fruit is allowed to fall naturally from the tree and is collected from the ground. This occurs during the rainy season. Yields vary considerably. A harvest of 5-15 kg of nuts (kernels with shells) per year per tree is said to be average, but harvests up to 45 kg from trees that were protected and well-tended have been recorded.

Shea butter is extracted using several variants of the basic traditional method. The procedure used by the Mossi of Burkina Faso can be taken as representative: The freshly collected fruits are placed in pits and kept moist for several days to ferment. After the loosened pulp has been pulled off, the

Shea is often the principal economic resource underpinning the lives of those inhabiting vast areas where little else saleable can be found or grown. According to estimates, the tree provides more than half women's income in the rural Sahel. Foreign exchange is also earned: both seed-kernels and the butter are shipped to Europe and Japan, where they are processed into baking fat, margarine, cocoa-butter substitutes, and various highly touted beauty aids. (FAO photo/P. Cenini)

nuts are cleaned, boiled or roasted, and dried. They are then pounded and crushed to break off the hard brown shell and expose the kernel (or "almond"). Shaking and winnowing the mixture, as if it were grain, removes the particles of broken shell. The kernels are then air-dried to approximately 10 percent moisture, at which point they neither germinate nor decompose and can be safely stored for months without spoiling.

Next comes the main task. The dry kernels are heated over an open fire until they start "weeping." This exudation of oil means they have reached the temperature at which the solid fat liquefies: 38°C. The hot kernels are

then poured into a mortar and pounded using a heavy pole or flat rocks. This task is so long and so onerous that several women generally share the burden. The result is a reddish-colored paste. After cooling, this paste is rolled-out flat so the bigger impurities can be picked out. The fatty residue is then poured into a vessel and alternately rinsed in hot and cold water. Finally, it is kneaded, cooked in an iron pot, and steadily kneaded again with a rhythmic tumbling action until a white layer of fat rises to the surface. This "virgin" shea butter is skimmed off and wrapped tightly in leaves. This first-run, top-quality product may be stored for a long time. The rest is either reprocessed or discarded. Even such incredibly toilsome efforts recover only 36-40 percent of the fat in the kernels.

Of course considerable quantities of the kernels are also handled using modern methods. In Europe, especially, shea kernels are extracted using the expensive machinery designed for mass-processing other oilseeds: continuous screw press, filter press, and/or hydraulic presses. Industrial-scale extraction recovers at least 80 percent of the kernel's fat.

LIMITATIONS

Uncertainty over the harvest is certainly a prime limitation. Shea tends to bears fruit once every two or three years. In any year, two trees in three may produce almost nothing.

African mistletoe already affects a large portion of the shea population, including almost all of Burkina Faso's trees.

As has been shown, the fat is terribly difficult to refine. Making things worse, the nuts contain latex, which clogs filters and other machinery parts. Solvent extraction is also difficult, as the latex prevents the solvent from penetrating the mass. To reduce latex problems the nuts must start out bone dry, something not easy to accomplish in a village during the rainy season.

If not thoroughly purified, the fat goes bad. The decomposition begins in the fresh nuts. These are naturally low in free fatty acids when they fall from the tree, but if handled improperly they quickly turn rancid. It is recommended that freshly harvested nuts be boiled an hour (to denature the fat-splitting enzymes) and then dried in the sun.

NEXT STEPS

Since the 1940s and 1950s relatively little solid research has been undertaken on shea until recently. Many aspects remain poorly understood. In spite of its local and national economic importance, modern data on how best to produce it and its foods is still hard to come by. Further research is needed on virtually everything but, thankfully, much is at-last already underway. Though many of the challenges listed below may take years to resolve, anyone seeking answers today should first consult information and experts via the Internet.

Basic Aspects of the Tree The tree's biology and physiology are still very uncertain. To mention just one example, shea corymbs (the fan-shaped, flower clusters) carry several dozen flowers, but as far back as 1948 it was reported that only 2 to 4 of those flowers are fertile. Studies of pollination and reproductive biology could possibly point the way to increasing fruit production many fold and perhaps regularizing the annual yields as well.

Experts have yet to find the reason behind shea's irregular fruiting cycle. It seems probable that the bush fires and the hot dusty wind called harmattan contribute to the flowers and buds dying prematurely. Drought may also play a part. However, none of these is sufficient explanation in itself. There probably is a fascinating physiological explanation still awaiting discovery.

Basic research on the influence of climate and soil on the tree's productivity, growth, and unreliable bearing is needed as well.

Propagation Fresh seed germinates readily but viability declines significantly within a week or so unless the seed is cooled. The deep-rooted seedlings can be difficult to establish if transplanted. There has been some success with air-layering and grafting of superior clones, as well as tissue-culturing, but more experience is needed before standard practices are fully developed and acceptable. One special difficulty is the long period needed to reach fruiting age. Traditionally, shea was believed to take about 20 years to bear fruit, with full production only reached after about 50 years! Although experience generally bears out long lead-times, well-tended trees on a plantation at Sapone in Burkina Faso bore fruits after a dozen years. Whether such substantial differences are genetic or environmental requires further study, as it has significant bearing on prospects for domestication and non-seed propagation. There is also high yield variability among different trees, so further identification and propagation of selected germplasm is of high importance. The Cocoa Research Institute of Ghana has started one such a program, but it is a very long-term process. Vegetatively propagated materials may eventually reduce initial fruiting to only a year or two.

Regeneration of Parklands The only way to stop desertification across the Sahel is to protect the vegetation. Clearly, with its widespread presence and fire-proof trunk the shea should be in the forefront of any effort to slow, stop, or reverse the expansion of the Sahara effect. At the farm level, the low-performance individual sheas could be replaced over time or reworked by grafting on branches from high-performing trees. In addition, fallows could be seeded with quality planting materials. Additionally, means such as vetiver-grass hedges or fertilizer or pest controls could be applied to regenerate trees existing in the parklands.

Although shea has occupied the savanna parklands for millennia, the tree densities over the last few decades have declined in many places. Drought,

population pressure, and landuse change have killed some and decreased the regeneration of others. However, probably the greatest concern is the very high level of parasitism by the four mistletoes (*Tapinanthus* species). These parasitic plants are hard to combat. Approaches that have been suggested include herbicide control, physically removing the parasite from infected trees, killing the birds that pollinate mistletoe and disseminate its seeds, and boosting the populations of bird species that eat those particular seeds that land in the top of a shea tree. These and other possible methods need to be tested for safety and effectiveness, and quickly turned into practical controls.

Food Technology Traditional methods of extracting shea butter cannot meet today's needs, let alone tomorrow's. Researchers have identified several easier and more efficient ways to handle the nuts and still produce good quality butter locally. Although improving, these do not yet live up to their full promise, and continued diligent effort is sorely needed. Local production is crucial for a reason beyond local consumption: Africa exports more than 10 times more butter in seeds than as finished product, thus losing all that potential value-added profit

Using machinery to reduce the human drudgery is clearly necessary. This is not a novel notion. Mechanized shea processing has already been introduced to West Africa. Some uses sophisticated technology, some "appropriate technology."[5] Mainly, these approaches have involved mills to crush and grind the nuts, but there have also been attempts to use centrifuges to process the butter better and solar driers to dry the nuts. Solar technology has become very popular in West Africa, and solar driers are an especially intriguing possibility to ease handling the fresh kernels. This, as well as perhaps other techniques, would reduce the possibilities of the nuts decaying when they are stored in their shells, increase the efficiency of roasting and boiling the nuts, remove the tedium of extracting the oil, increase the recovery rate of the fat, and improve the storage qualities as the shea moves from savanna to salon.

Horticultural Development The current average production per tree is estimated at about 10 kg of fresh fruit. Clearly, this could be increased. A tree the size of an oak should be capable producing much more, and up to 200 kg has indeed been reported. Particularly good trees are well known and greatly prized in certain locations. Now is the time for a registry, so seed and cuttings can be collected and the production of quality plants for mass use made possible.

Overall "superiority" is not an easy thing to pin down, however. It might be based on the nut (the number, size, and butter quality, for instance). It

[5] The processing presses usually run on diesel or electricity, but now many manual models are becoming available.

might be based on the pulp (weight and sugar content, maybe). It might be based on the tree's growth characteristics. Individual trees with early, lengthy, or semiannual flowering may be of over-riding value for improved overall production. As standards are determined, the heritability of such production characteristics from superior trees raised through seeds also deserves study.

Arguably, the greatest of all research needs is vegetative propagation. This needs further research improvement, because it permits ready multiplication of superior trees. Perhaps the main problem behind all the vegetative methods is the plant's latex, which literally gums up the grafts. This is common to trees of this family (Sapotaceae). Indeed, another member of the family is sapodilla (*Manilkara zapota*), which is the original source of chewing gum. Sapodilla and sapote (*Pouteria sapota*) are commercially grown in tropical America. The special techniques developed for those latex-filled relatives might help open new possibilities for shea. Tissue culture should also be more widely explored, although here time-to-maturity once again becomes an issue, as does the added possibility of genetic off-types only revealing themselves after years of growth and investment.

There is also need for garden-variety horticultural research. With shea the possibilities for individual contributions are great. For instance, management of seedlings and trees needs improvement, and the use of mineral and organic fertilizers for faster growth and better fruiting deserve assessment.

Increasing Output At least in theory, production could be vastly increased in one simple way: collect more of the nuts. Presently, the natural wealth of the shea tree is not fully exploited, and much—even most—of the wild crop goes unharvested each year.[6] There are an estimated 94 million shea trees in Mali, for instance. Theoretically, therefore, that country alone could produce 80,000 tons of nuts a year, which could transform its economic standing in the world.

In this regard, more knowledge is needed on land tenure and how the tree rights are distributed among household members and community groups. This is important because new processing technologies and new market opportunities will make the crop more valuable, and inevitably lead to conflict over the trees' ownership. Research should be conducted to anticipate the consequences, good and bad, particularly to the traditional users, notably women. In many places, it may be simply that available labor is insufficient when the nuts fall, and simple techniques—manual or mechanical—that are used with other plants to collect "windfalls" may close

[6] In one survey it was found that only 43 percent of the total crop was harvested. Information from Brent Simpson.

this gap.

The cause is also partly economic. Current prices do not encourage farmers to fully utilize this resource. Demand and price are strongly influenced by the availability and cost of other vegetable fats, especially cocoa butter, so the price is not always controllable. Because of this and other factors, many harvests must be sold when local prices are low. Indeed, the women mostly sell on a seasonal basis, when the markets are already flooded with shea butter. Possible answers may include producer cooperatives, direct marketing, and shea-storage facilities. The small producers would then at least earn more money.

Product Research According to some observers, shea's future depends on developing uses for its unsaponifiable matter. This non-fat part of the seed displays several interesting physical and biomedical properties that could have pharmacological and cosmetic applications. These higher-value uses include prevention of skin drying, the soothing of sore skin, protection and lubrication, fast release and long retention of active ingredients, and high UV absorption.

Further research is therefore needed on the properties and applications of the unsaponifiable matter. Recognition of shea butter's unique properties and applications could result in big price increases at the point of sale. In theory, higher profits would then encourage capital investment in its production. And that could help fund research to make shea a booming resource for the whole Sahelian region.

SPECIES INFORMATION

Botanical Name *Vitellaria paradoxa* C.F. Gaertn.

Synonyms *Butyrospermum paradoxum, Butyrospermum paradoxicum* ssp. p*arkii, Butyrospermum parkii, Lucuma paradoxa* (Gaertn.) A. DC

Family Sapotaceae

Common Names[7]

Arabic: lulu, sirreh (Chad)
Bambara: se, berekunan, tamba
Burkina Faso: taanga (moore)
English: shea, shea butter, butternut tree, bambuck or galam butter
French: karité
Dioula: karité ("life")
Fulani: kareje

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[7] The tree has many names in Africa. The English name shea, is derived from its Bambara name, se.

Ghana: sukpam (Frafra); nku or ngu (Ashanti); yokumi (Volta)
Hausa: mai, k'danya, bagay
Wolof: karité
Peuhl: kare, kolo

Description

This is a stout tree that can grow up to 20 meters tall with a trunk over a meter in diameter. It is deciduous, but never looks it because the new leaves arrive at the same time the old ones fall. The crown is dense and many-branched; its shape very variable. In adult trees, the bark is dark, thick and deeply cracked into squares, like crocodile skin. The leaves are tough and strap-like, mostly clustered at the ends of branches. There is an extensive root system, essential to help the tree survive the seasonal or multi-year droughts of the savanna climate.

The brownish or creamy-white flowers are also mostly clustered at the ends of branches. They seem pollinated by insects, mostly bees. The fruits ripen during the early rainy season. They are spherical or ellipsoid berries 3-6 cm long, borne on a stalk (peduncle) 1-3 cm long. The pulp is yellowish-green and sweet.

The nut at the center of the fruit consists of a thin brown shell enclosing a single, dark-brown, egg-shaped kernel, inside which is the fatty substance known as shea butter. The nuts are about 3 grams in weight. Sometimes they contain more than one kernel.

Distribution

Within Africa Shea occurs in the southernmost parts of the Sahel and the adjacent Sudan and Guinean savannas. Senegal is the western extent of its range.[8] Dense stands are found from Guinea through Mali, Burkina Faso, and Niger. The trees also occur in Guinea Bissau, Sierra Leone, Côte d'Ivoire, Ghana, Togo, and Benin as well as Nigeria and Cameroon. East of this region, there are scattered occurrences across Central Africa from Chad through Sudan to far-western Ethiopia, Uganda, and Congo.

Beyond Africa The tree is, as far as we know, unknown outside Africa except for a report from Honduras, where it is called "tango."

Horticultural Varieties

Although elite single specimens are known and reproduced by seed, and provenance trials of vegetative material are underway, there seem to be no

[8] In Senegal it grows only sporadically in the extreme southeast, around Tambakounda, Casamance.

true-to-type varieties. The species itself has been divided into two subspecies, subsp. *paradoxa* and subsp. *nilotica*. The former is found at lower altitudes (up to 600 m and occasionally much higher, but always west of the Nile drainage basin), is more drought-resistant, and takes longer to sprout (up to five months).

Environmental Requirements

Shea grows in the dry forests and savanna with a very marked dry season of 6-8 months. There are also periodic droughts that go on several years. It also occurs scattered in dry forests throughout the Sudano-Sahelian zone, but does not extend into coastal areas. It is a light-demanding species of open sites, mostly solitary, and over its principal ranges commonly forms pure stands.

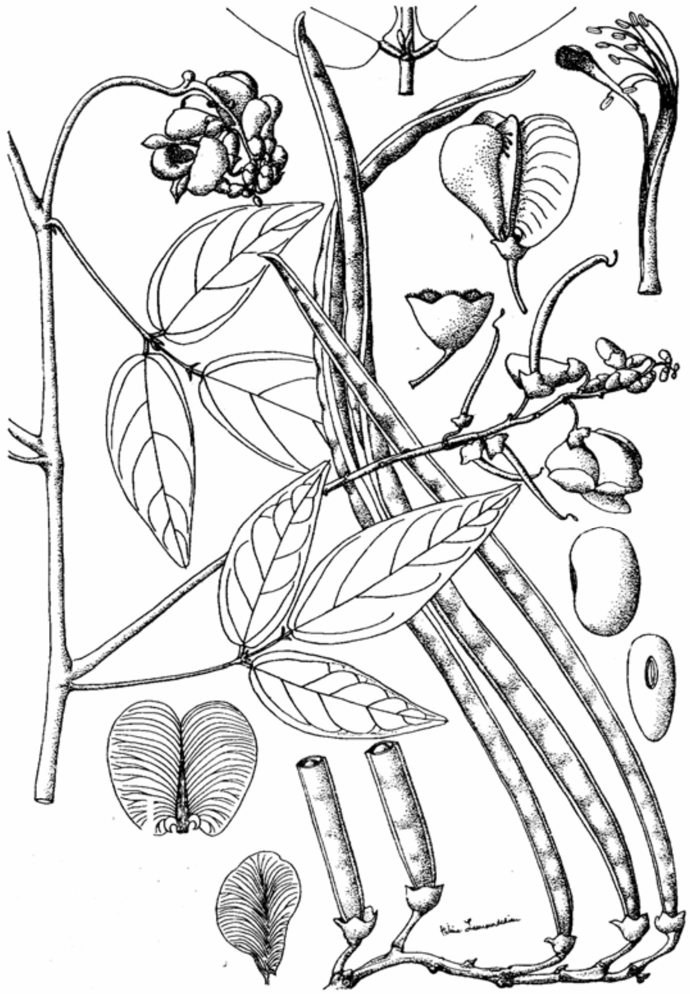
Rainfall Shea is found in areas with 400-1,800 mm rainfall per year. However, the trees are most common and healthy where they receive 600-1,200 mm and where the dry season lasts no more than 8 months.

Altitude Shea grows generally at low altitude, although on Cameroon's Adamaua Plateau it ascends to 1,200 m above sea level.

Low Temperature It grows in areas characterized by average annual temperatures of 24-32°C. The minimum is reported to be 21°C.

High Temperature Temperatures where shea is found commonly climb into the lower 40s.

Soil Shea occurs naturally on the dry slopes of the savanna zone, but not in alluvial hollows or land subject to flooding. It is found on various soil types but seems to prefer dry and sandy clay soils with a good humus cover. Nonetheless, it tolerates stony sites and lateritic subsoils, although its yields may not be great.



Sphenostylis stenocarpa (Hochst. *ex* A. Rich.) Harms

18

YAMBEAN

The plant known internationally as yambean is arguably one of the most interesting of all the world's new food crops.[1,2] This species, which hails from the Americas, looks like a bean plant above ground but is actually grown for the swollen roots it produces below ground. Since the dawn of history these yam-like tubers have fed tropical Americans. Then Spanish galleons[3] carried the seed across the Pacific, and this productive, palatable, and nutritious legume subsequently spread through Asia and became a market-garden favorite from China all the way to India.

In recent decades yambean has taken on renewed momentum and is now among the world's fastest rising new crops. Already it is the top selling specialty vegetable in the United States, its tubers being sold in many (if not most) U.S. supermarkets under its Mexican name, jicama. Americans buy the round, squat tubers for use in salads, for replacing scarce water chestnut in Chinese cooking, and for a low-calorie snack food. Demand has risen to such an extent that Mexico now exports half a million tons annually.[4]

In Europe, this food is catching on, too. Part of Thailand's large yambean output, for instance, is now shipped to many Asian stores in major European cities. This American crop has even entered production trials in Portugal, where, under conditions seemingly so different from its native tropical habitat, it has demonstrated very impressive yields: 54 tons per hectare, with up to 24 percent dry matter containing 10 percent crude protein.[5]

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[1] Several *Pachyrhizus* species go by this name, but the best known and best developed yambean is *Pachyrhizus erosus*. It mostly goes by local or indigenous names, including fan-ko (China), sankalu (India), sinkamas (Philippines), dolique tubereux or pais patate (French), Knollige Bohne (German).

[2] Information in this chapter relies heavily on Sørensen, M. 1996 *Yam bean (*Pachyrhizus *DC.)*. International Plant Genetic Resources Institute, Rome, and personal communications with this tireless Danish crop champion.

[3] Amazingly, these galleons crossed the Pacific from Mexico to the Philippines annually without fail for 400 years.

[4] Its wholesale price has reached $2.50 a kilo, an amazing figure for a root crop traded in bulk.

[5] The yambean here was the Andean species (*Pachyrhizus ahipa*), and the range of

Seeds of three varieties of African yambean from farmers' fields in Nigeria (soybean lower-right for comparison). The seeds are notably nutritious, and experiments in Nigeria have yielded of 2 tons per hectare, an exceptional amount for an undeveloped legume. Starting from such a base, the African yambean—given good research support—would seem capable of ultimately yielding as much as the best bean crops. (Thomas Betsche)

More to the point, though, is the fact that during the last few years yambean has also arrived on Africa's shores. Here, too, it has been a smash hit, creating what a researcher describes as "remarkable success in a number of West African countries." Again, yield was the major draw. In trials carried out in Benin, for example, two genotypes produced around 80 tons of tubers per hectare.[6] At separate locations in Senegal, the per-hectare production was 40 and 100 tons.[7]

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protein contents, measured on a dry-matter basis, was 9.6-11.1 percent. The plantings were made in Tras-os-Montes, a northeastern province of Portugal where the climate is distinctly Mediterranean.

[6] Both the Mexican yambean (*Pachyrhizus erosus*) and the Amazon yambean (*Pachyrhizus tuberosus*) were introduced to Benin. The yield mentioned here was measured in two varieties of the Mexican species. In addition, in Benin one Haitian cultivar of the Amazon yambean produced a yield of 70-80 tons per hectare, which is certainly not to be sneezed at. Further introductions have been made to Congo and Ghana. In tests in Mexico, the local yambean has yielded 160 tons of tubers per hectare, perhaps a world food-production record.

[7] The Senegal figures were recorded on research stations at Bambey and Tiago, respectively.

That is an enormous quantity of food for such a small area to produce and, although the tuber has a rather exotic texture and taste, West Africans have taken to it. Indeed, thanks to local media coverage, it has generated such intense public interest that the biggest problem, so an observer reports, is finding enough seed to meet the need. Stemming from this has come one unforeseen consequence: "A peculiar situation has arisen," the observer writes, exhibiting great circumspection, "with several of the field trials subjected to 'unauthorized testing and sampling' at night by local farmers!"

Given all these developments across the various continents, it seems little wonder that this species is steadily climbing upward toward becoming a truly global resource. But a seldom-recognized fact is that Africa has its own counterpart. The so-called African yambean (*Sphenostylis stenocarpa*) is not uncommon in central and western Africa, especially southern Nigeria. Outside tropical Africa, however, no one has seen it and few heard of it. Indeed, not only has the African yambean not taken even a baby step toward being a global resource, it actually is moving in the opposite direction…toward extinction.

Although classified as belonging to a different genus, the African yambean is closely related to the American version and also is grown for its fleshy swollen roots. Its tubers, however, are elongated and look more like sweet potatoes than yams. In nutritional terms, they are a class above the mainline root crops, containing more than twice the protein of sweet potatoes, yams, or potatoes and more than ten times that of cassava. Moreover, the protein is of exceptional nutritional quality, superbly complementing the proteins of maize, sorghum and the other staples. Eating African yambean together with those major foods helps provide the body a "complete protein." The combination, in other words, closely matches the chemical requirement for constructing the thousands of separate proteins human bodies need to make constantly.

And that is just one of the surprises this minor and almost lost crop conceals. Another is that this almost unknown African resource surpasses its transatlantic counterpart by producing both edible seeds and leaves in addition to the edible tubers.

All yambeans are unusual in that they are legumes, a plant family renowned for peas, beans, soybean, peanut, and other nutritious seeds, but not for edible roots. Yet the yambeans' swollen underground stems are succulent, white, sweet, mildly flavored, and crisp as a fresh-picked apple. They can be eaten out of hand. They can be used to add crunch to green salads and fruit salads. They can be steamed or boiled, and have the unusual property of retaining their crispness even under conditions that convert potato to mash. In cooked form they taste like potato, but whereas it averages 5 percent protein, African yambean tubers have from 11 to 19 percent protein (on a dry-weight basis).

And good taste and good nutrition are just the start of the appeal. African yambean appears to combine qualities that make it attractive to the farmer, the processor, the consumer, AND the environment: good adaptability to a wide range of climates and soils, reliable yield, a good balance between protein and starch, agreeable taste, good shelf-life, biological nitrogen fixation, and energy efficiency.[8]

All this makes one wonder why a species combining the reliability of a root crop with the protein content and high sustainability of a legume is not better known. Certainly, Africans familiar with the plant regard it highly. Trouble is, only a few of the continent's 600 million inhabitants have heard of it, let alone tasted it. It is mainly restricted to pockets of West and Central Africa, where smallholders grow it exclusively for their own use. Thus, even within the region that knows it best much of the populace is unaware of the botanical gem in their midst.

That botanical gem remains unpolished, however. Perhaps because it seldom enters commerce to any degree, it has received little formal recognition from the agricultural authorities. Indeed, there is so little understanding of it that only sketchy summaries and a scattering of research papers highlighting specific technical features can be found in the international literature.

Yet African yambean is not unimportant in people's lives. Cultivated in Nigeria mainly for seed, it is also grown for tubers in Côte d'Ivoire, Ghana, Togo, Cameroon, Gabon, Democratic Republic of Congo, Ethiopia, and parts of East Africa, notably Malawi and Zimbabwe.

Moreover, the plant is adaptable, and capable of growing anywhere that common yam is cultivated.[9] Indeed, it could be grown in many more locations than that, not to mention grown much more successfully in those locations where it already exists. A vigorous vine that climbs and twines to heights over 3 m, the plant thrives in weathered soils where the rainfall can be extremely high. It tolerates even the acid, infertile, highly leached sites that are the humid tropical lowlands' special curse.

Part of the reason for this adaptability to bad substrates is that like other members of the legume family, the African yambean enjoys a symbiosis with bacteria that fix nitrogen from the air. The invisible bacterial microbes inhabiting its roots relieve the farmer of the necessity to supply additional nitrogenous fertilizer. They also make the plant a fine candidate for sustainable development purposes. This is, in other words, a food source that supports itself while helping both the soils under it and the species that succeed it.

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[8] Regarding this last point, the tubers can be consumed fresh, thereby saving wood and other cooking fuels. Soaking overnight is very useful to reduce cooking time.

[9] In many cases both plants are cultivated together, and one theory holds that the plant's English name comes from this combination. More likely, though, the name developed because the plant has "yams" on bottom and "beans" on top.

And the African yambean is no slouch in the yield department, either. It produces its seeds, tubers, and biomass in abundance:

As far as the seeds are concerned, experiments in Nigeria have demonstrated yields of 2 tons per hectare,[10] an exceptional amount for an undeveloped legume. Starting from such a base, the African yambean, given good research support, would seem capable of ultimately yielding as much as the best bean crops. As mentioned, the seeds are notably nutritious, with crude-protein levels ranging from 20 to as high as 29 percent. Although this is less than the amount in soybeans (38 percent), the protein contains levels of essential amino acids likely to make African yambean seed the soybean's nutritional equal. Lysine, for example, comprises up to 8 percent of the protein, and methionine and cysteine together may comprise 2.4 percent.

But it is the below-ground product that is of greatest immediate interest. The tuber yield varies between cultivars and has not been pinned down with precision. Nonetheless, it is generally high. If grown in pure stands, 100,000 plants per hectare is a reasonable field density, and each produces up to 500g of tubers. This already good figure can undoubtedly be raised—possibly dramatically—merely by preliminary research attention.

Of the biological nitrogen fixation, only a few details have been reported. Hopefully, the actual amount fixed can eventually be raised to a level similar to that of its American counterpart: 200 kg of nitrogen per hectare.[11] In that transatlantic species, about half the nitrogen, or more than 600 kg protein per hectare, accumulates in the tubers. This is an amazing amount for a hectare of root food. It approaches or exceeds the stellar seeds of soybean and peanut, which are considered world protein-production leaders.

Any root crop even vaguely capable of delivering record quantities of protein from soils normally considered marginal would seem to deserve intense global attention. For all its potential, though, African yambean remains a neglected, even primitive, resource. There has never been a concerted steady effort to advance it, despite the fact that throughout the tropics root foods are increasingly sought. Because of this neglect, the farmers who know it best are switching to crops for which more help is available, and sadly their heritage of seeds and age-old wisdom with the crop are slowly fading away.

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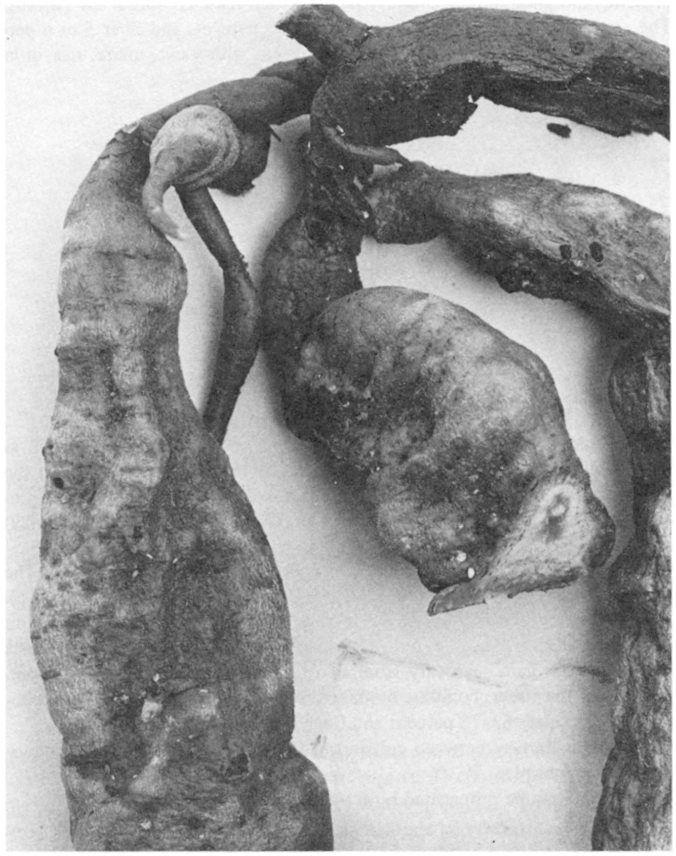
[10] Out of 63 lines from a germplasm collection at the International Institute of Tropical Agriculture in Ibadan, Nigeria, the most productive line yielded 1,860 kg of seed per hectare. Yields of 2,000 kg per hectare have been recorded at a research station in Nsukka, Nigeria.

[11] These figures, measured in three cultivars of the Mexican yambean, *Pachyrhizus erosus*, were 163-216 kg of nitrogen per hectare, of which 70-75 percent was produced through fixation of atmospheric nitrogen (based on isotopic ^{15}N methods). Castellanosa R., J.Z., F. Zapatab, V. Badilloa, J.J. Peña-Cabrialesc, E.S. Jensend, and E. Heredia-García. 1997. Symbiotic nitrogen fixation and yield of *Pachyrhizus erosus* (L) urban cultivars and *Pachyrhizus ahipa* (Wedd) Parodi landraces as affected by flower pruning. *Soil Biology and Biochemistry* 29(5-6):973-981.



African yambean tubers, with their succulence and crunchy texture, could appeal to millions of palates. Moreover, it grows easily and is well suited to the difficult environment of the hot wet tropics where the climate and conditions now constrain local diets to far less nutritious foods. (International Grain Legumes Information Centre)

This trend must be changed. A plant that perhaps could benefit millions of the malnourished deserves urgent attention. The highly efficient way in which it absorbs nitrogen makes it an especially attractive tool for helping farmers whose land is worn out. Moreover, it grows easily and is well suited to the difficult environment of the hot wet tropics where the climate and conditions now constrain local diets to far less nutritious foods. And the tubers, with their succulence and crunchy texture, could appeal to millions of palates. Possibly the African yambean could do much more than just help subsistence farmers eat better…it might make a valuable cash crop across regions that desperately need a biological fulcrum for leveraging rural development upwards.

PROSPECTS

Given the fact that little has yet been done to advance this neglected vegetable it is hard to project how far it might ultimately go in helping humankind. Nonetheless, some sense of the promise can be grasped by a quick comparison with its transatlantic counterpart, which as noted has become one of the fastest rising new food crops and is already a megamillion-dollar resource.

Within Africa

Humid Areas Excellent. The plant is found growing through much of tropical Africa and is fully at home in lowland areas where the rainfall is high and nutritious crops hard to come by.

Dry Areas Unknown. In Nigeria the species is cultivated from the tropical forests to at least the savanna's edge. The issue of growing it in dry areas is less one of biology than of economics; root crops typically are drought resistant but they need copious water to yield profitably.

Upland Areas Excellent. Although often classified as a low-altitude legume, it seems little affected by height above sea level, and flourishes at elevations up to at least 2,300 m.

Beyond Africa

In other tropical regions of the world this plant would likely thrive, but no one has tried to find out.

USES

Seeds and tubers represent the primary food, although the plant also has potential utility producing feed for livestock and green manure for soil restoration.

Seeds The seeds may be eaten alone or in soups, and are commonly served with yam, maize, or rice. They are said to be delicious and to be "often preferred over other types of beans."[12] The leathery or slightly woody

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[12] Although "field reports" are overwhelmingly positive, antimetabolic factors common to other pulses (such as soybean) have been found in the laboratory (see Limitations), and stomach cramps, diarrhea, and dizziness have been reported from Nigeria (Azeke, M.A., B. Fretzdorff, H. Buening-Pfaue, W. Holzapfel, and T. Betsche. 2005. Nutritional value of African yambean (*Sphenostylis stenocarpa* L): improvement by lactic acid fermentation. *Journal of the Science of Food and Agriculture* 85(6):963-970; an online overview, "Food safety and security: Fermentation as a tool to improve the nutritional value of African," is available at tropentag.de/2005/abstracts/full/463.pdf). It is unclear

pods are typically bundled together and hung over the fireplace, where they stay safe until consumed or sold. The beans extracted from the dried pods are prepared in several ways. Many are partially roasted over a fire and eaten together with palm kernel. Others are soaked several hours, boiled 4 to 6 hours, and eaten like common beans. In another procedure, they are squeezed with palm oil and chili pepper as well as various spices and vegetables to form a paste, which is wrapped in banana leaves and heated over the coals. In every case, so it is said, African yambean seeds make a nutritious, filling, and tasty meal.

Roots The tubers are eaten either raw or cooked. The exact details are still unclear, but some idea of their eventual utility can be inferred from the yambean in Mexico, where:

- Raw tubers are cut into sticks and sprinkled with lime juice and chili;[13]
- Fresh tuber slices are added to salads of both the dinner and dessert kinds;
- Cooked tubers are used on their own or with other vegetables to prepare soup;
- Chopped tuber is added to Oriental stirfries;
- Tubers are grated and boiled in milk to create a tasty drink;
- Sliced or diced tubers are pickled with onion and chili to form a popular snack food; or
- Tuber segments and green beans are preserved in vinegar as a sort of three-bean salad.

Leaves Although the leaves are said to be edible, nothing more than those few words are on record, so the extent, mode, and safety of eating them remain uncertain. The leafy vegetation remaining from the harvest provides useful fodder. Likely, it is very beneficial to livestock, due both to its protein content and the massive quantities produced.

Sustainable Agriculture Of all the 17,000 nitrogen fixing species in the plant kingdom, yambean seems to be among the most efficient. On a per-hectare basis, the American species has been recorded as regularly producing 120-150 kg of nitrogen.[14] This is higher than that recorded in other grain-legume residues, and gives yambean an important role in crop

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how genetically or geographically widespread these factors are (see Next Steps).

[13] On the streets of places like Mexico City, vendors sell these as a cooling snack for hot and harried passersby.

[14] The plant populations in the trials were 110,000 plants per hectare and the flowers were pruned to force greater tuber growth. Castellanosa R., op. cit.

rotations, a fact known for centuries in tropical America. In many traditional farming systems in Mexico, for instance, the crop is employed to restore soil fertility after years of cropping maize and cassava and cotton and other nutrient-draining species. African yambean could well prove to have a comparable soil-restorative capacity. Already, there is preliminary evidence that African yambean could make an excellent species for crop rotations, for ground cover, for binding soil and related purposes.[15]

Other Uses With its prolific spattering of large, colorful, dangling flower clusters—pink, purple, or greenish white, among other hues—this vine makes a vivid ornamental, reminiscent of wisteria (although the flowers are much smaller and the inflorescences are upright, rather than hanging).

NUTRITION

African yambean is a nicely rounded non-fat food: from 50-75 percent carbohydrate, 20-25 percent protein, around 1 percent oil, and 5 or 6 percent fiber, all providing nearly 400 calories per 100 g dry-weight. Although the protein is produced in copious quantities, that is not necessarily the ultimate measure of a proteinaceous foodstuff. More important is the protein's nutritional *quality*, because a protein lacking certain minor components is nutritionally next to useless. In a protein, quality is judged by the incidence of a few amino acids, and many plant proteins, being deficient in lysine and methionine, are low in nutritional quality. On the other hand, African-yambean seed protein contains those two in abundance: lysine 7-8 percent and methionine 1-2 percent. And the levels of the other essential amino acids enhance that already exceptional condition. In one seed sample, for instance, the overall complement was: cysteine 1.9, leucine 6.6, lysine 8.3, methionine 1.2, phenylalanine 4.8, threonine 3.3, and valine 4.1 percent.[16]

As mentioned, the tubers are nutritious too. The raw protein in those swollen root tissues amounts to 11 to 19 percent, which puts the plant into a nutritional class above the major root crops. The tuber protein is also of high quality: cysteine 1.8, isoleucine 4.5, leucine 7.7, lysine 7.6, methionine 1.7, phenylalanine 4.5, threonine 4.3, and valine 5.5 percent. Adding to the tubers' nutritional contribution is their 63-73 percent content of carbohydrate and their 3-6 percent fiber. The starch alone has been put at 65 to 70 percent and about 370 overall calories.[17]

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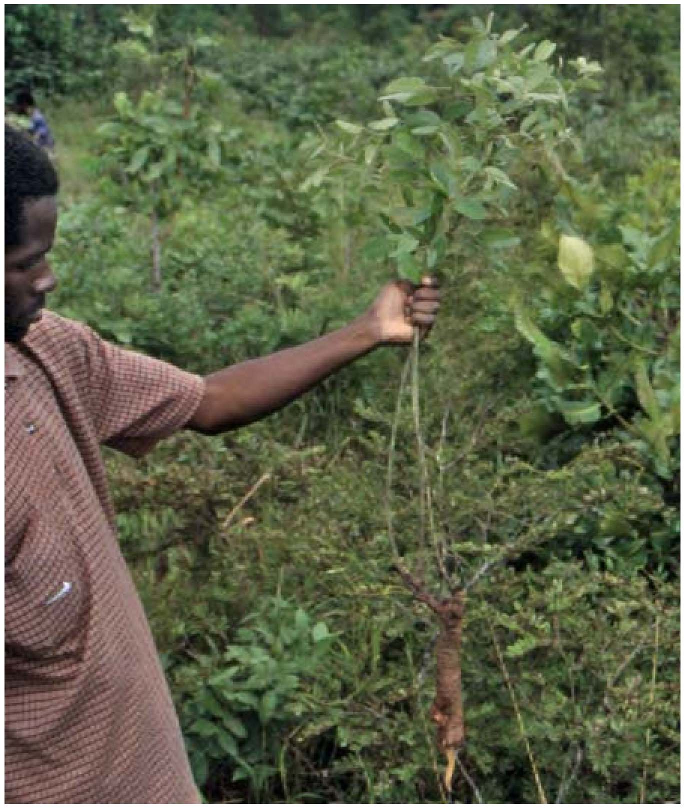
[15] Contributor Dieter Kleiner reports, "we've made a small experiment which demonstrates that *S. stenocarpa* is an excellent biofertilizer."

[16] All figures are given in g per 100 g protein. Ezueh, M. I. 1984. African yam bean as a crop in Nigeria. *World Crops* 36(6):199-200.

[17] These tuber component figures are also from Ezueh, ibid.



Chimaliro Forest, Kasungu Province, Malawi. African yambean is a legume whose fleshy swollen roots look something like sweet potatoes but are succulent, sweet, and crisp as a fresh-picked apple. In nutritional terms, they are a class above the mainline root crops, containing more than twice the protein of sweet potatoes, yams, or potatoes and more than ten times that of cassava. Moreover, the protein is of exceptional nutritional quality, superbly complementing the proteins of maize, sorghum and the other staples. In addition, both seeds and leaves are edible. And the African yambean is no slouch in the yield department, either. It produces its edibles in abundance, and seems capable of delivering record quantities of protein from soils normally considered marginal. (Søren Døygaard)

The true importance of the quality proteins from both beans and tubers lies in their ability to complement cereals such as maize and sorghum as well as roots such as yam, cassava, and sweet potato. When measured against the uncompromising necessities of human nutrition, those staple foods are deficient in essential amino acids. This fact of nature creates a nutritional crack in the foundations of Africa's food supply because people living primarily on cereals and roots (which includes many of the poor, the sick,

and the very young) can run out of a dietary essential amino acid. When that happens their bodies stop producing *all* protein—brain, muscle, hair, antibodies, enzymes, blood cells, skin, and the rest. In such situations, the addition of even a small amount of the missing essential amino acid from, say, yambean raises the overall protein effectiveness out of all proportion and restores the bodily processes to normal operation.

For children, especially, yambean may be valuable in this regard. In normal situations, adults eat cereals with sauces that contain small amounts of protein and vitamins. But children typically find the sauces too peppery and are served cereals without that special nutrient supply. Adding some yambean would make up for the loss. In addition, children can nibble on the raw tubers to get quality protein.

HORTICULTURE

Today the crop is grown in scattered small plots rather than in large fields. Although it can be cultivated alone, it is mostly grown with yam or maize. At the beginning of the wet season farmers plant it using seeds, small tubers, or pieces of root. Like yam, it is normally planted on ridges or little hills. It is also normally supported on trellises or stakes—often the same ones supporting the yam vines. However, tests in Nigeria suggest that it grows and yields tubers satisfactorily even unsupported.

If the maximum yield of tubers is desired, the above-ground parts should be severely pruned back. We don't know how widespread this "reproductive pruning" process is in Africa, but in the Americas it is considered the key to achieving big yambean tuber crops. There, both the flowers and flower buds are pruned as many as four times a season, with the first cut being made about 2 months after planting. The target is the reproductive parts; a few flowers may be left for seed production, but the rest, and the main growing shoots, are rigorously removed. The plant responds by pumping its energy into the parts underground.

Normally no special irrigation is applied. Nor is nitrogenous fertilizer needed, although experience in Mexico suggests that a shot of phosphorus could be helpful.

Pests are seldom serious, and typically they are the same ones affecting other legumes in the area. One report lists the African yambean's major insect attackers as bean pod borer (*Maruca testulalis*), stem-boring beetle (*Sagra adonis*), and the variegated grasshopper (*Zonocerus variegatus*). The exact mix of pests, however, is likely to vary with location. Controls that work on other legume crops should prove equally effective on African yambean.

Diseases are also similar to those of other local legumes. The main fungal threat is downy mildew (*Phytophthora phaseoli*). An unidentified yellow mosaic virus has been observed attacking the plant in Nigeria.

Like most legumes, this one is highly susceptible to nematodes.

HARVESTING AND HANDLING

The African yambean typically begins flowering 80-120 days after planting. Pods start maturing at about 150 days after sowing. From then on, flowering and pod formation continues for as long as the climate remains conducive. As a practical matter, though, harvesting usually ceases after 60 days.

The tubers develop more slowly than the flowers, normally taking 5 to 8 months to swell to harvestable size. Most are dug up toward end of the rainy season. They can, however, be harvested early (if local preferences encompass small or medium sized tubers) or they may be left in the soil for a time after the rains cease.

As to handling the tubers, methods developed for the related species in Mexico probably apply. There, the ridges or little hills of soil are loosened with a hoe or with a crossbar mounted on a tractor. Each tuber is then lifted by hand, and the vegetative top is removed with a pair of shears and left in the field for later use as forage or organic fertilizer. Finally, the tubers are collected, sacked, and stacked for shipment.[18]

The optimal storage temperature for the Mexican tubers is given as 12.5-17.5°C. And the only treatment given them is washing, trimming (to remove roots and stem parts), and dipping in hypochlorite solution to sterilize and bleach the surface. The tubers then remain usable for about a month, provided they are kept indoors and well ventilated. The African yambean tubers can probably be treated similarly.

LIMITATIONS

A number of limitations need be kept in mind:

- The crop is slow to mature and is considered sensitive to daylength.
- As in many beans (and other foods), the raw seeds contain trypsin and alpha-amylase inhibitors, tannins, oxalates, saponins, and phytic acids, as well as "potentially very toxic" cyanogenic glycosides (especially in white seed) and flatulence-causing alpha-galactosides.[19] These levels were improved somewhat by thorough cooking (see below), and the levels likely vary significantly among different genotypes (as in common and lima bean). An alternate route suggested by the authors was *Rhizopus*- and lactic-acid fermentation, as used with soybean, which greatly reduces most of these antinutritional factors with much less energy cost, while yielding additional fermented foods for this part of the world, where such delicacies are already

[18] Alternatively, they are loaded straight into trucks and whisked to a local market, to Mexico City, or to the northern border for cleaning and repackaging, and onward shipment to US supermarkets.

[19] Azeke, et. al., op. cit.

so popular. Others have shown it makes good dawadawa paste.[20]

- The dry beans need lengthy cooking, traditionally 4-6 hours (like most beans) but much longer (up to 12) to apparently have significant impact on undesirable compounds.[21]
- Certain peoples prefer certain seeds. Southern Nigerians, for instance, like darker types, while northerners want brightly colored seeds.
- High moisture content makes yambeans shrivel and lose condition more quickly than the mainstream root crops.
- Bean weevils (bruchids) can attack the seeds in storage, as they do other beans.
- The beans reputedly "sit heavy in the stomach" and are said to cause thirst and wind.

NEXT STEPS

Clearly, this crop deserves the attention of modern science. There is little doubt that both basic and applied sciences can dramatically increase its productivity and usage. As of now, though, this foodstuff is known only in Africa, so most initiatives must be local.

Many research avenues can help make the crop more productive and more useful. Some are presented under the headings below.

Surveying the Scene A first priority should be the development of baseline African-yambean knowledge, including such things as geographic limits, traditional uses, and standard cultivation practices. Such basic expeditions can be simple, inexpensive, and enlightening.[22] An initial survey in Ghana, for example, found "[African yambean] is used extensively in various dietary preparations and has potential for supplementing the protein requirements of many families throughout the year." Important actions include:

- Initiating countrywide searches to locate the crop and its farmers;
- Documenting the methods traditionally employed for growing it;
- Publicizing the methods traditionally employed for cooking the different parts (including leaves);
- Assessing natural genetic differences throughout its range; and
- Collecting and evaluating representative germplasm.

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[20] Wokoma, E.C. and G.C. Aziagba. 2001. Sensory Evaluation of Dawa Dawa Produced By the Traditional Fermentation of African Yam Bean (*Sphenostylis Stenocarpa* Harms) Seeds. *Journal of Applied Sciences and Environmental Management* 5(1):85-91

[21] Ibid.

[22] G.Y.P. Klu, H. M. Amoatey, D. Bansa, and F. K. Kumaga. 2001. Cultivation and use of African yam bean (*Sphenostylis stenocarpa*) in the Volta Region of Ghana. *Journal of Food Technology in Africa* 6(3):74-77

The pool of knowledge resulting from such initiatives can provide insight into the African yambean's existing limits, possibilities, and extension priorities. It will also point out ways by which farmers can be helped to manage the plant more intensively, more securely, and more productively. It will, in other words, provide preliminary guidance on the present status and the future steps, including best practices for planting, cultivating, controlling pests and diseases, harvesting, handling, and cooking the crop.

Support for Farmers Preliminary surveys should be quickly converted into advice to help those who are the keepers of Africa's age-old yambean heritage. They should become, in other words, part of the extension agents' advisory tasks throughout the yambean zone. The goal is to stop any more farmers abandoning the crop if they don't really want to. Toward that end, other actions that can be mounted include:

- Marketing initiatives. African yambean should be quickly tested as a cash crop. In Mexico, the tubers sell for three times as much as cassava, and provide profit to farmers small and large.
- Taste tests and other popularizing activities.
- Demonstration plots. Local agronomists should undertake trials to optimize production. These would best be done in the local fields with the owner's participation—perhaps incorporating a measure of competition among, and financial reward for, the best local yambean growers. The psychology of getting the growers involved may be as important as any technical advances achieved.

Food Technology

Almost nothing is known about the basic properties of the various African-yambean foodstuffs. Investigations should now be conducted into basic features, including:

- *Digestibility and Antinutritional Factors* Trials on the actual digestibility of seeds, tubers, and forage are required. For example, alpha-amylase inhibitors in the seed could reduce caloric uptake while increasing the intestinal gases for which many beans are renowned. The challenge posed by other antinutritional factors should also be examined. In particular, the presence and fate of potential cyanogenic glycosides in both raw and cooked portions should be traced from plant to plate, just as they have been in soybean, cassava, sorghum, and other staples carrying these compounds.
- *Culinary Issues* The long cooking time is a barrier to the plant's wider use as a bean crop. Needed now is a search for the cause as well as for quicker-cooking types. As a first step, the starch in the seeds as well as the skin around them should be compared with those of other beans, such as

cowpea, common bean, and bambara bean, and correlated with the cooking time.[23]

- *Recipes* Home economics groups should involve themselves in the rescue of this ancient native. The development of dishes for both seeds and tubers is one need. Yambean tubers, for example, may well prove an attractive addition to various traditional dishes, as well as a popular snack.
- *Pods* In India, young American yambean pods are eaten like French beans. Now is the moment to test African yambean counterparts to see if they have any value as "tropical snow peas." The key is to search for and to measure the occurrence and fate of antinutritional factors such as rotenone.

Leaves The safety of eating the leaves (presumably as a boiled vegetable) deserves assessment.

Starch The chemistry of the tuber starch deserves investigation. Although it is said to be "comparable to that of cassava flour," the granules are supposedly distinctly different.[24]

Curing Tests on the storage of African yambean tubers are needed. Once the vegetative top has been removed, smallholders tend to leave the tubers in the ground until eaten or sold. The fate of the starch, protein, and other components under such treatment needs investigation. In the American species the tubers get much sweeter and more valuable when "aged."[25]

Plant Physiology This is the moment for an all-points inspection of the species itself. A plant as promising and yet as little understood as this one needs almost everything looked at. Topics needing exposure include:

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[23] Where electricity or gas is available, pressure cookers would speed up cooking and improve digestibility. Some years ago, structural changes in yambean tubers as a result of microwaving was studied. Treated tuber pieces were fed to rats and found to have a digestibility much greater than fresh tubers. Schmar, T.A., C.A.Z. Harbers, and L.H. Harbers. 1987. Structural changes in jicama (*Pachyrrhizus tuberosus*) with microwaving and digestion in rats. *Nutrition Reports International* 35(4): 771-774. Microwaving, a technology now found surprisingly often in rural Africa, also reduces antinutritional factors in many types of legumes. Hernandez-Infante, M., V. Sousa, I. Montalvo, and E. Tena. 1998. Impact of microwave heating on hemagglutinins, trypsin inhibitors and protein quality of selected legume seeds. *Plant Foods Hum Nutr* 52(3):199-208.

[24] Interestingly, the tubers of the Amazon yambean have proven to be virtually pure amylopectin, and the possibility of utilizing it in non-food products is currently being investigated.

[25] In Bolivia some producers sweeten up their tubers by putting them in a sunny place for up to 2 weeks. In a previous test, the sucrose content tripled and the starch dropped by 80 percent after 3 months of storage at 12.5°C. Paull, R.E., and N.J. Chen. 1988. Compositional changes in yam bean during storage. *Hortscience* 23:194–196.

- *Nitrogen Fixation* The efficiency of biological nitrogen fixation under both greenhouse and field conditions should be examined. Field collections of some indigenous strains of *Rhizobium* and *Bradyrhizobium* have been carried out, but the selection of genotypes and strains with high potential for nitrogen fixation still awaits.
- *Protein Chemistry* The biochemical, topochemical, and structural characterization of protein bodies of seeds and tubers need investigation.
- *Seed Features* The issues of seed set, seed size, and seed components deserve study.[26] One especial need is to check the content of rotenone in the mature and maturing seeds.[27] The different genotypes' ability to retain germination capacity during long-term storage also needs analysis.
- *Soil Requirements* Tests should be run on soils of different pH, density, and fertility levels.

Genetic Development In order for this crop to remain attractive to local farmers, improved cultivars are needed. High priority should be given to those benefiting the traditional smallholders of West and Central Africa.

The plant's dual propagation capability is a feature that will speed the process along. This is a rare crop that can be sexually propagated by seed as well as clonally propagated by tuber or root tissue. For one thing, it can be bred in the normal way using crosspollination and the resulting progeny can be multiplied clonally. This allows for flexibility, speed, and efficiency.

Genetic improvement targets of opportunity include:

- Higher yields;
- Bigger tubers;
- Seed of select colors;
- Bush-type plants that stand by themselves without staking;
- Daylength-insensitive plants that make the crop more reliable across seasons and latitudes;
- Fast maturity. Early maturing cultivars are known in yambean, and likely exist in the African form as well;
- Quick-cooking seeds;
- Lower levels of potential antinutritional factors;
- Thick-skinned tubers that don't bruise during shipping and have a long shelf life; and
- Tubers of good size and taste for consumer acceptance.[28]

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[26] In the Mexican species there is said to be a strong positive correlation between seed size and yield.
[27] Although unreported in African yambean, this alkaloid is found in the leaves and pods of New World yambeans.
[28] Consumers prefer different sizes and tastes. Mexicans and Americans, for example, demand the tubers be crunchy and juicy and weighing 0.35-0.9 kg with a sap that is

Although the above research initiatives are individually important, the ultimate target should be drought-tolerant, photothermally neutral, and pest- and pathogen-resistant cultivars capable of producing high yields and nutritious, tasty food over a wide range of climates and soils.

Exploring the Wild Resource The genetic characteristics for horticultural development highlighted above are likely present in the wild ancestor from which the cultivated form developed. They may also be present in the crop's wild relatives: *Sphenostylis angustifolia* (endemic to South Africa), *Sphenostylis briartii* (native to Congo), *Sphenostylis erecta* subsp. *erecta* (Central Africa, East Africa), *Sphenostylis erecta* subsp. *obtusifolia* (southern Africa), *Sphenostylis marginata* (southern Africa), *Sphenostylis schweinfurtii* (Central and West Africa), and *Sphenostylis zimbabweënsis* (Zimbabwe).

Sphenostylis schweinfurthii is an especially interesting species, characterized by having hairy stems and hairy leaflets that making it more resistant to drought—a feature of potential interest in breeding.

These wild relatives deserve genetic evaluation, too. Such investigations could help pin down the African yambean's ancestry. They could expose the cross-pollination success ratio, and thereby provide insight into the closeness of the genetic relationships. They could also uncover qualities that might be usefully bred into the cultivated crop.

Agronomic Exploration Although little is known about its environmental tolerances, the plant is recommended for small-scale cultivation trials in tropical regions outside its native habitat. These should be collaborative tests conducted at different altitudes, latitudes, soils, and climatic conditions, notably humid and semiarid ones. One outcome will be clarifying the plant's suspected daylength sensitivity.

Comparisons among the yambeans of commerce would also be instructive. In this regard, the African one should be put into head-to-head trials with the three New World species (and perhaps with the yam itself). The differences and similarities will teach much, to the benefit of them all.

With all the emphasis on tuber production, there has been little work on optimizing seed production. Means that have successfully increased seed yield of better-known bean crops deserve to be also applied to this species

With any viney crop the issue of plant support is paramount. It is therefore critical to rapidly test whether the African yambean really does yield tubers satisfactorily when unsupported. And if it indeed does need supports, to find the cheapest, simplest, and most effective ones.

Reproductive pruning. Because of the obvious competition between tuber

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watery rather than milky and a slightly sweet taste. Southeast Asians, on the other hand, want their yambeans 0.25-0.6 kg with a bland flavor.

growth and seed production, there is a need for field studies to clarify the effects of pruning in the more promising landraces.

Propagation In-vitro techniques are a possibility for rapidly multiplying rare genotypes for conservation purposes, or of hybrids or new material from field collections or field trials. If biotechnology can make available such genotypes in quantity, it would mean field evaluations could be made almost immediately afterwards, and especially good material could be quickly moved to growers.

Industrial Development Although today strictly a subsistence crop, the African yambean might well prove a valuable provider of industrial resources. Several products are possible on a local or sizable scale:

- *Flour* The large tuberous roots can undoubtedly be dried and ground to form a top-quality flour, useful for cakes, desserts, and other culinary purposes. The properties of this flour should be comparable to those of cassava flour, but perhaps more nutritious and profitable. In India, tubers from the Mexican yambean are ground this way and the flour is considered to be high grade.
- *Sugar* African yambean tubers need testing as a sugar source. Whether any possess practical quantities of sugar is unknown, but their cousin from the Andes (*Pachyrhizus ahipa*) has proven to contain more than twice the sugar found in sugar beet.[29]
- *Protein* Even though the protein content of the tuber is lower than that of grain-legume seeds, the total protein yield per hectare for the tubers exceeds that of soybean, the world's premier protein crop. African yambean may therefore have a future as a source of protein for people, pets, livestock, laboratory animals, and industrial processes.

Sustainable Development With its high biological nitrogen fixation, yambeans may return a substantial amount of nitrogen to the soil. The crop therefore could form an integral part of land-use systems, benefiting land and people. Programs developing sustainable African agriculture should include African yambean in appropriate trials.

In parts of tropical America, yambean plays an important role in crop rotation systems. It is grown in the same field for two consecutive seasons, producing a higher yield in the second than the first. Starting in the third season maize, beans onions, or other crops are planted there instead. Then, after a break of 3 or 4 years, yambean is returned to the field again to restore the fertility lost to the interim harvests. In Africa's generally worn-down

[29] In one test, the Andean yambean had 47 percent sugar. Sugar beet, a crop of considerable industrial importance, contains 20 percent sugar.

soils, a rotation like this might prove even more effective at sustaining land productivity.

SPECIES INFORMATION

Botanical Name *Sphenostylis stenocarpa* (Hochst. ex A. Rich.) Harms.

Synonyms *Dolichos stenocarpus*, *Vigna katangensis, Vigna ornata,Vigna ornata var. latifolia, Sphenostylis congensis, Sphenostylis ornata, Sphenostylis stenocarpa var. latifolia*

Family Leguminosae. Subfamily: Papilionoideae (Faboideae)—Pea family

Common Names

English: African yambean, otili
French: pomme de terre batéké, pempo
German: Yambohne
Ghana: kutreku, kulege, akitereku, apetreku
Nigeria: girigiri, kutonoso, roya, efik, nsama, ibibio
Malawi: cinkhoma, nkhoma
Ibo: okpo dudu
Obudu: bitei
Togo: sesonge, gundosollo, sumpelegu, tschangilu
Yoruba: sese, sheshe
Congo: giliabande, pempo, mpempo
In Africa this crop goes by a multiplicity of local names, which have yet to be systematically collected.

Description

The species is a perennial that is usually grown as an annual. The cultivated type is a twining, herbaceous vine 1 to 3 m long. The stems are strongly branched and are often reddish in color. They bear trifoliate leaves up to 14 cm long. The individual leaflets are oval with pointed tips and smooth edges.

The butterfly flowers, borne in racemes up to 30 cm long, have twisted petals 2.5cm long, and are probably insect-pollinated. The color is variable and not only includes pink, purple, and greenish white, but also yellowish white, red, magenta, lilac, and blue.

Most blooms develop into narrow pods, 20 to 30 cm long and about 1 cm wide. They are pointed and are subdivided inside by fine transverse walls. The ripe ones are brownish in color and up to 30 cm long. They contain 20-30 seeds. The seeds themselves are large (up to a cm long) and can vary from white to brown and black. Some are speckled or marbled in brown and white, and there veined seeds are known as well. The hilum has a brown

border.

The root system typically branches vigorously. However, some roots thicken into the storage organs. These spindle-shaped tubers outwardly resemble sweet potatoes but taste more like potatoes. In general, they are from 5 to 25 cm in length and weigh 50-300 g (average 250 g). The smallest are normally kept aside and used for planting the next crop.

Distribution

Within Africa Although African yambean is obscure in a general sense, it exists in a number of countries. In broad terms, the cultivation area extends from tropical West Africa to Sudan, Eritrea and northern Ethiopia. From there it extends southward to Congo in the west and Zanzibar in the east. However the greatest importance, without a doubt, is in West Africa, primarily Nigeria and its immediate neighbors.[30]

Beyond Africa At the time we write this, the plant seems unknown outside Africa.

Horticultural Varieties

Only local landraces are grown, though some accessions are named.

Environmental Requirements

Although little is known about its needs, a humid tropical climate with well-drained soil seems necessary or at least best.

Rainfall According to claims in the literature, the crop requires between 900 and 1,400 mm annual precipitation.

Altitude Seemingly little affected by altitude, it flourishes at elevations from sea level to 1,800 m.

Low Temperature Almost certainly sensitive to frost.

High Temperature The limit is unreported. Good growth is possible between 19 and 27°C.

Soil Type The crop is mostly cultivated on poor soils. Its optimal

[30] Overall, the species has been found (wild and/or cultivated) in the following countries: Angola, Burundi, Cameroon, Central African Republic, Chad, Congo, DR Congo, Eritrea, Ethiopia, Gabon, Ghana, Guinea, Kenya, Malawi, Mozambique, Nigeria, Rwanda, Sudan, Tanzania, Togo, Uganda, Zambia, and Zimbabwe.

substrates are said to be weakly acid, with pH 5 to 6. The site should be well drained. Fertile sandy soils are said to be "highly suitable."[31]

Related Species

The African yambean is so closely related to *Vigna* species that a botanist once classified it as *Vigna ornata*. This genus—an important one for food in the tropics—includes moth bean, mung bean, bambara bean, rice bean, cowpea, and adzuki bean. Modern techniques, including embryo rescue, might allow the production of interspecific hybrid combinations between it and the other two cultivated species. This suggestion is a stretch, but if it proves possible the resultant plants could be particularly valuable in developing cultivars that are early maturing, heat- and day-length neutral, bushy, and better adapted to new areas.

[31] Root crops typically yield worst in heavy soils that confine the tubers and keep them from swelling.

Appendix A

BIOGRAPHICAL SKETCHES OF PANEL MEMBERS

Dr. Norman Borlaug, Chair, is Senior Consultant to the Director General of CIMMYT (International Maize and Wheat Improvement Center), as well as Distinguished Professor of International Agriculture at Texas A&M University, and President, Sasakawa Africa Association. A Member of NAS (1968), Nobel Peace Laureate, and Founder of The World Food Prize, he is the recipient of nearly 60 honorary degrees. Dr. Borlaug's early work in plant pathology, wheat breeding, and agronomic systems has since led him to become one of the best-known spokespersons and ambassadors for tropical agriculture and food security. He has been particularly influential at engaging political leadership to integrate agricultural policy into national planning. Dr. Borlaug has had a broad impact on global agricultural research and production, has helped train a generation of agricultural scientists, and remains deeply involved in enhancing African agriculture through the Sasakawa Africa Association and its Global 2000 Partnership with the Carter Center, whose mission is raising the productivity of African farmers through sustainable development and equitable and responsible use of resources. Borlaug is from the U.S., and has a doctorate in plant pathology from the University of Minnesota.

Dr. Anthony Cunningham, Director of Ethnoecology Services in Fremantle, works predominantly with the WWF/UNESCO/Kew "People and Plants Initiative", which he helped found and for which he worked as African Regional Coordinator from 1992 through 2000; he is also engaged by the Centre for International Forestry Research. An ethnoecologist whose work focuses on the applied ecology of natural-resource use by people, his early research was on traditional foods in southern Africa. He has since worked across the continent (and elsewhere) investigating the interactions of humans with their environment by examining, especially, field management of useful plants. With his focus on the relationships among agriculture, resource exploitation, and conservation, much of his research has been tied to

implementation processes promoting collaborative resource management programs between local communities and outside influences such as government, NGOs, and conservation or commercial interests. Among other awards, he has received the occasional Sir Peter Scott Award for Conservation Merit from the IUCN Species Survival Commission (1999), and the EK Janaki Ammal Medal (2002) from the Indian Society of Ethnobotanists for significant contributions and achievements to the field. Cunnningham is from South Africa, and has a doctorate in botany from the University of Cape Town.

Dr. Jane I. Guyer is currently Professor of Anthropology at Johns Hopkins University, after moving in 2002 from Northwestern University where she had been Professor of Anthropology and Director of African Studies since 1994. Professor Guyer, a Woodrow Wilson Fellow in 2003, specializes in African studies, social anthropology, and the study of production and distribution systems, in particular the anthropology of the economy and material life in West and Equatorial Africa. She focuses primarily on the growth and change of indigenous economies, with a special emphasis on food economies and money management outside structured systems. Professor Guyer has authored and co-authored numerous books and articles; her most recent single-authored book is *Marginal Gains: Monetary Transactions in Atlantic Africa*, which focuses on the function of popular economic systems in Africa, from crisis conditions to ordinary household budgets. Guyer, a U.S. citizen, is from England, and has a doctorate in anthropology from the University of Rochester.

Dr. Hans Herren has been President of the Millennium Institute since 2005. Dr. Herren earlier served as Director General of the International Centre of Insect Physiology and Ecology (ICIPE) in Nairobi for twenty years, prior to which he was with the International Institute of Tropical Agriculture. He is an NAS Foreign Associate (1998), and President of the International Association for the Plant Protection Sciences. An agronomist and entomologist, Dr. Herren has spent most of his working life in Africa, where his research has been on the field-level union of science-led information with local production systems, particularly emphasizing pioneering applications of integrated pest management. His latest research efforts address poverty alleviation, sustainable agricultural productivity, and biodiversity conservation in Africa. Herren's contributions to improving Africa's food security, particularly research and control of the cassava mealybug through the world's largest biological control project, have been recognized through many awards,

including the Tyler Prize for Environmental Achievement and World Food Prize "in recognition for having advanced human development by improving the quality and availability of the world's food supply". Dr. Herren also currently serves as the Editor-in-Chief of the ICIPE-hosted journal, *Insect Science and its Application*, and is on the Editorial Board of *Biological Control Science*. Herren is from Switzerland, and has a doctorate in agricultural sciences from its Federal Institute of Technology.

Dr. Calestous Juma is Professor of the Practice of International Development and Director of the Science, Technology and Globalization Project at the John F. Kennedy School of Government at Harvard University. He is a Member of NAS (2005), and has served on many NRC committees. He is also a Member of the Kenya National Academy of Sciences and a Fellow of both the New York Academy of Sciences and the World Academy of Art and Science. Dr. Juma is former Executive Secretary of the United Nations Convention on Biological Diversity and founding Executive Director of the African Centre for Technology Studies in Nairobi, an independent public policy research institution. His research interests, beginning with field work with indigenous vegetables in Kenya, include biological diversity and biotechnology, evolutionary and systems theory, science and technology policy studies, institutional change, and international trade and international environmental policy. He has worked as a teacher, science writer, chief executive officer, and advisor (including USAID), has served on the governing and advisory bodies of several international organizations, and has won many international honors. Dr. Juma has written widely on issues of science, technology and environment, including *Science, Technology and Economic Growth: Africa's Biopolicy Agenda for the 21st Century*. United Nations University, Tokyo (2000). Juma is from Kenya, and has a doctorate in science and technology policy studies from the University of Sussex.

Dr. Akinlawon Mabogunje was Chair of the Development Policy Centre in Ibadan, Nigeria until retirement, and serves as co-convener of the international Initiative on Science and Technology for Sustainability. He is also Chairman of the Nigerian Presidential Technical Committee on Housing and Urban Development. He was formerly Professor of Geography, Dean of the Faculty of the Social Science, and Director of the Planning Studies Programme, University of Ibadan, and was also President of the International Geographical Union. He is an NAS Foreign Associate (1999) and is currently a Member of the Committee

on the Geographic Foundation for Agenda 21. He also served as Chairman of the Committee on Human Settlements of the Scientific Committee on Problems of the Environment (SCOPE) of the International Council of Scientific Unions. In addition, he was Chairman of the Advisory Committee of the Urban Management Programme of the United Nations Centre for Human Settlements/United Nations Development Programme and the World Bank, was Vice-Chairman of the Directorate of Food, Roads and Rural Infrastructure, Office of the President, Nigeria, and Executive Chairman of the National Board for Community Banks. Dr. Mabogunje's work seeks to understand continuity and development of rural/urban/regional interactions in Africa over time, with increasing attention to future issues of sustainability. These interactions are especially close in Africa, and his research on the relative contributions of internal and external systems affecting them have recast many assumptions underlying development there. In particular, his work has called attention to the persistence of indigenous structures whose better understanding and utilization can help to more effectively unleash development energies of the people, especially in the rural areas. Among his many published books and academic papers are *Urbanization in Nigeria, Regional Planning and National Development in Africa; The Development Process: A spatial perspective*; and (as editor) *The State of the Earth: Contemporary Geographic Perspectives*. Mabogunje is from Nigeria, and has a doctorate in geography from University College London.

Dr. Barbara Underwood, Adjunct Professor of Nutrition (in Pediatrics) at Columbia University, was until recently Scholar in Residence at the U.S. Institute of Medicine, and is the Immediate Past President of the International Union of Nutritional Sciences. Prior to retirement she was Chemist at the National Eye Institute of the U.S. National Institutes of Health, where she also served a secondment as Scientist in the Nutrition Unit of the World Health Organization. Dr. Underwood has broad field association with the great variety and analyses of foods eaten by humans, with 40 years global experience in research and training related to international nutritional deficiency and maternal/child health problems, with recent years devoted to development of global policy and guidelines for the control of micronutrient deficiencies of vitamin A, iron, and iodine. Her work is based on the interactions among food, nutrition, and health in developing countries, with research interests emphasizing studies on vitamin A metabolism, nutritional status assessment, and functional consequences of deficiency. Her laboratory developed and first applied in human populations the Relative Dose Response (RDR)

test to indirectly identify depleted vitamin A stores. In addition, her research and training interests have focused on nutritional problems of mothers and children in deprived circumstances, and she has more than 150 publications in basic and applied nutrition and nutritional biochemistry. Dr. Underwood has served on many international committees, advisory and editorial boards, and consultancies, including USAID, as well as board member of numerous foundations and advisory groups. Underwood is from the U.S., and has a doctorate in nutritional biochemistry from Columbia University.

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Appendix B

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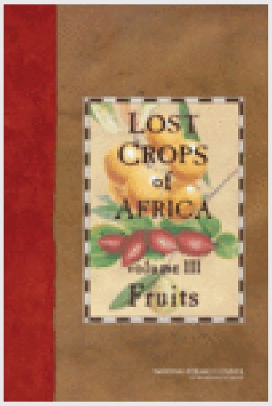
"Africa always produces something new"

Pliny the Elder, after Aristotle



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More than 1,000 people have participated in the National Research Council's overall study of the crops of Africa. Most contributed by nominating species of grains, fruits, nuts, vegetables, legumes, oilseeds, spices, sweeteners, and beverage plants they deemed worthy of inclusion. All those individuals played a part in developing this, the third product from the study. The following list, however, includes especially the ones who provided technical details that became incorporated into chapters of this particular book.

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PREFACE

This book is one of a series identifying innovations with promise for improving the quality of life in the earth's poorest regions. Like its predecessors—more than 30 reports extending over 30 years—it combines the knowledge of experienced individuals into a study crafted to provide insights, particularly for decision-makers at every level from the farm and village to the nation and beyond. This volume draws special attention to Africa's traditional fruits. Specifically, it emphasizes 24 cultivated and wild resources that seem useful for diversifying food supplies and improving nutrition across the hungriest continent.

Why such a seemingly obvious examination is needed results from a peculiar situation. Within the huge hungry zones below the Sahara are to be found several thousand native food plants, almost none of which have been given research or technical support. Plants that have fed people for millennia go largely or wholly without scientific or development attention today, even as millions in their midst suffer chronic malnutrition and related ills.

We call such neglected riches the "lost crops of Africa." Among these forgotten foods a significant fraction are fruits. By highlighting a small selection we hope these pages demonstrate not only the potential latent in these few, but also inherent in the full array of Africa's indigenous edibles.

It is important to understand our use of the word "lost." As in the case of "lost cities," such as Zimbabwe, this is a word applying to an outsider's perspective. The foods described here are not truly lost; indeed, in many locations many are beloved companions, especially by rural populations. It is the mainstream of international science and people beyond the rural regions that remain unaware of the resources described here.

This book is the third in a study highlighting the promise inherent in the food plants indigenous to Africa. Each presents information useful to help a continent where millions confront severe and interlocking problems stemming from difficulties in food production and food distribution. The first volume, published in 1996, covered a dozen grains:

- African Rice (*Oryza glabberima*)
- Finger Millet (*Eleusine coracana*)
- Fonio (*Digitaria exilis* and *D. iburua*)
- Pearl Millet (*Pennisetum* species)
- Sorghum (*Sorghum bicolor*)
- Tef (*Eragrostis tef*)
- Other cultivated grains (*Brachiaria*, *Triticum*, *Paspalum*, etc.)
- Wild grains (*Echinochloa*, *Paspalum*, etc.).

Volume II, which published in 2006, covers 18 vegetables:

- Amaranth (*Amaranthus* species)
- Bambara Bean (*Vigna subterranea*)
- Baobab (*Adansonia digitata*)
- Celosia (*Celosia argentea*)
- Cowpea (*Vigna unguiculata*)
- Dika (*Irvingia* species)
- Eggplant (*Solanum aethiopicum*)
- Egusi (*Citrullus lanatus*)
- Enset (*Ensete ventricosum*)
- Lablab (*Lablab purpureus*)
- Locust Bean (*Parkia biglobosa*)
- Long Bean (*Vigna unguiculata*)
- Marama (*Tylosema esculentum*)
- Moringa (*Moringa oleifera*)
- Native Potatoes (*Solenostemon rotundifolius* and *Plectranthus esculentus*)
- Okra (*Abelmoschus esculentus*)
- Shea (*Vitellaria paradoxa*)
- Yambean (*Sphenostylis stenocarpa*)

Both those books and the current one stem from questionnaires in which Africans and Africa specialists nominated sub-Saharan food plants they considered underexploited. The resulting recommendations exceeded even the combined capacity of these three tomes. Indeed, the current trilogy outlines only a fraction of Africa's home-grown food heritage.

In fashioning the present volume, we chose to separate the resources based roughly on their uppermost level of management. Thus, the first section describes fruits that are cultivated at least to a small extent. These 10 chapters are, by contrast with the rest, longer and more detailed and the plants described are, scientifically speaking, better known. Part 2 describes 14 species that are still essentially untouched by the almost-magic hand of modern horticulture. Necessarily, these descriptions are more sparse and the conclusions more uncertain.

Every chapter began as a skimpy draft prepared from library sources as well as miscellaneous documents we had on hand. That first round included more than 40 different fruit types. Each description was mailed to the original nominators as well as to others located via the scientific literature and our own efforts. Their comments, corrections, and improvements were subsequently evaluated and integrated into a second set of drafts.

In turn, those upgraded descriptions were emailed to scores of specialists identified through the emerging Internet, yielding yet another round of insight. By this point more than a dozen fruits were clearly less worthy than

the rest and were summarily dropped. Next, the cultivated and wild fruits introductory sections were compiled from the accumulated information, much of it never publicly available.

Finally, the panel (page v) considered the end product of this extensive technical outreach. They evaluated the balance of the work and especially assessed introductory sections to ensure the overall thrust was in accord with their experiences with Africa's problems, needs, and potentials. A final draft was then reviewed in accordance with procedures approved by the National Academies' Report Review Committee.

This drawn-out process of writing and review led to the present work. As with the companion volumes, this is neither a textbook nor a survey of African botany or agriculture. It is a selective work that stands somewhere between a scholarly account and a popular review of 24 essentially independent fruit resources. The chapters are internally organized for easy access by administrators, entrepreneurs, plant lovers, and many more who could help release these overlooked resources from international obscurity.

This book is thus intended as a boost to African development, not a bequest to academe. Our goal is to leverage indigenous fruits into greater production, helping them achieve their innate capacities as well as raise nutritional levels, diversify agriculture, facilitate environmental stability, and open economic opportunities in a continent needing all those things.

Because our audience is broad, each chapter is organized with more than one set of readers in mind. The opening pages employ a general tone and are intended primarily for non-scientists and newcomers unexposed to the species in question. Subsequent text incorporates increasing levels of detail by which specialists and the cognoscenti can assess the relevance of these species for themselves, their region, or their research. This, the opposite of normal scientific writing style, has in the past worked well for our purposes of increasing awareness.

It should be noted that certain items of interest to readers beyond Africa's shores have been included. This is partly because in the past African crops have sometimes been belittled as merely "marginal foods"—as if lack of status in science equated to a lack of significance in (someone else's) society. Mainly though, it is because our pages highlight reasons why *everyone* should help resurrect Africa's forgotten foods.

Anyone interested in working with these fruits can easily find those of greatest interest by consulting the separate Introductions to Cultivated Fruits and Wild Fruits. There, the overall promise of each species is summarized in one paragraph, and then placed in the context of overcoming malnutrition, boosting food security, fostering rural development, and sustainable landcare. For convenience, the overall potential is also ranked in tables (see Tables 1 & 2), which also show where these fruits primarily occur in Africa. For further information, we recommend readers turn first to the Internet,

where it now seems each day there is new information on these old crops.[1]

The first volume in this series—the one dealing with cereal grains—was written in the age before computers brought the world to our fingertips, and included appendices describing tangential technical breakthroughs and scores of selected readings. In the present volume we've curtailed similar addenda. Such changeable particulars are these days more surely uncovered and updated electronically and, unlike limited printings of books, can be accessed by millions just in Africa. We also once listed hundreds of research contacts complete with contact addresses and indicating sources of germplasm. However, because this report will also be digitally published, out of respect for electronic privacy we have eliminated listings of specific researchers and germplasm holdings; today these can easily be made known through the worldwide web. Moreover, with increasing bioconcerns over introduced organisms, as well as greater sensitivity to cultural heritage, the days in which individuals can freely exchange germplasm around the planet are past. Plant material today must always be transferred through appropriate channels according to phytosanitary, legal, and ethical norms. When dealt with safely and fairly, these crops will best approach their global potential.

****

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Academies' Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the process.

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[1] Much can be found by starting with Internet search engines, using scientific and common names for these species. On-line, an especially notable, coordinated effort to collect information on this broad diversity of plants is "Plant Resources of Tropical Africa" (prota.org), a joint African/European nonprofit foundation, which is documenting 7000 indigenous and introduced species useful in Africa. The International Centre for Underutilised Crops (www.icuc-iwmi.org) focuses on underexploited crop plants in particular, with extended monographs on several species. Some sites dealing with these plants (such as ecoport.org) are now organized by users themselves, sharing their input. Collaborative, user-driven electronic "portals" would be a boon for each of these species.

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Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Calvin O. Qualset, University of California, Davis. Appointed by the National Academies, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authors and the institution.

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A NOTE ON TERMS

Throughout this book the word "Africa" always refers to Africa south of the Sahara. Similarly, "African plants" always refers to sub-Saharan species, omitting North African plants, which in reality belong to the Mediterranean-Near East complex.

Since the book is written more for citizens than for scientists, we refer to the fruits by common names. Mostly, we use English names, except where those might imply that a plant pertains to a single social group or locale (e.g., Natal plum). Such epithets can spark resentment among others who might also reasonably regard a crop with equal passion, patriotism, or their own proprietary feelings. In a few cases we have not hesitated to feature a minor but mellifluous name. Our focus is the future, and a grating or quixotic name can discourage furtherance of an otherwise great fruit. Lists of common names are also included in many chapters. These are representative rather than exhaustive. In some cases almost every valley or village uses its own word.

Nutritional values are presented on a dry-weight basis, unless noted otherwise, to eliminate moisture differences between samples. Many of these figures were derived by obsolete methods or are otherwise tentative. Modern techniques can be rapid, accurate, and inexpensive, and should be applied to all these plants. Although for sake of simplicity we sometimes refer to vitamin A, readers should understand that within the fruit it occurs disguised as provitamin A carotenoids. These nutrients are converted to vitamin A in the body, but precise modern measures for these fruits are rare and conversion factors vary.

The fruits considered are those that are eaten in the normal way. Botanically speaking, coffee is also an African fruit but—even were it still "lost"—its form of usage puts it beyond our scope. In the same light, the miracle fruit, a headline-happy African species that contains a fascinating non-caloric sweetener, is excluded. Finally, there is the unique case of akee, a fruit much-beloved in West Africa and Jamaica. We have omitted it on the basis that use requires an intimate understanding of the ripening cycle of its fresh arils, both unripe and over-ripe fruits being poisonous.

For certain non-African crops we have employed internationally recognizable names. Examples include peanut for groundnut, papaya for pawpaw, and cassava for manioc. This is because this book will likely be read by people of influence in regions far beyond Africa's shores.

A WORD TO READERS

Everyone who works with plants assumes responsibilities. Some species described in this report—especially those which are less than domesticated—may be invasive or pestiferous outside their natural environs, and thus require due caution and on-going scientific assessment after introduction. Unless professionally inspected, they may also carry along unseen pests and diseases (particularly small insects and microbes such as virus or bacteria) whose populations might explode catastrophically in new locations. In addition, plant genes and germplasm are subject worldwide to both tangible- and intellectual-property laws; these legal rights hold especially true for food plants in which others—whether farmers or financiers—have already invested thought and labor or capital. For these reasons, most nations have official protocols based on intergovernmental conventions governing the safe and legitimate transfer of plant materials. These protect both people and the environment, and are rarely any obstacle to helpful activities. In the best interest of all parties, it is crucial that the requirements of such protocols be strictly followed.[2]

[2] Assurances may include at least a phytosanitary certificate and a written statement of consent (such as a material transfer agreement), and often a collection permit as well. Phytosanitary requirements for your country can be found by contacting your National Plant Protection Organization, listed on the website of the International Plant Protection Convention at www.ippc.int. Detailed information on proper access to genetic resources in conformity with the Convention on Biological Diversity can be found via www.biodiv.org.

FOREWORD

These pages highlight a collection of food plants that may seem to be just fruits. In reality, however, they are multipurpose assets for relieving problems across the vast and troubled landmass lying below the Sahara. The plights these fruits might lessen include hunger, malnutrition, rural poverty, devastation from unsustainable land practices, and their often-added burdens for women, mothers, and children. Even the suffering caused by fearsome disease might, to some extent, be relieved.

Such claims will perhaps seem overblown to the uninitiated. After all, the following pages portray mere plants. But consider this: the 24 resources highlighted here produce food of a particularly nutritious kind. Being fruits, they are among the priciest foodstuffs, many come from long-lived trees that protect land, and most are raised, harvested, and sold by women. Furthermore, in a continent beset by infectious diseases, the nutrients that come from fruits can boost general health, strengthen immunity, and help reduce the burden of disease.

For such reasons, all fruits should be larger contributors to Africa's diet. The advantage of the indigenous species we describe is that they are of African origin. These ancient foods evolved with humans as our ancestors ate their ancestors. The African landscape is already shaped by humanity preferentially selecting for these species.

Local origins are not, however, an unmitigated blessing. For one thing, it means that, with two glaring exceptions, these fruits are essentially unknown to those around the globe who most influence research priorities and funding decisions. For another, local pests and diseases have spent millennia perfecting their penetration of the plants' defenses.

These limitations, while substantial, are also manageable, and local fruits offer strong reinforcements for Africa's food security. When confronting the enormous challenge of helping sub-Saharan nations, outsiders—even those motivated by the best of intentions—hardly know where to start. The continent's problems seem impossibly complex—so intertwined and so overwhelming that there seems no place to even begin to build a solid base for solutions.

This book, however, identifies a wealth of entry points through which leverage can be exerted on several societal problems *at once*. Improving the plantings and productivity of baobab, to take a single example, would improve not just the rural landscape but also the social landscape, economic landscape, and even the topography of human health. Moreover, the improvement of baobab is a practical matter well within the capability of plant lovers, horticulturists, philanthropists, activists, educators, entrepreneurs and—most of all—innovative inhabitants of the lands where baobab trees thrive.

For such reasons African fruits deserve the scrutiny of science, but most of all they need the esteem and support of those who are not scientifically trained. Politicians and administrative authorities especially, in Africa and abroad, have yet to realize how much fruits can contribute to nutrition, to health, and to the general uplift in spirit that makes any nation, region, or continent great.

Africa's fruits can provide minerals and vitamins in locally available and attractive forms. They provide variety to the diet and taste buds, thereby enhancing the monotonous staples the impoverished masses endure day in and day out. They provide resources for small-scale horticultural enterprises and home gardens that represent a safety net for the rural regions and a prime means for raising income and relieving poverty in locales needing those most. Beyond all that, fruit trees hold fragile lands together, combating such encroaching calamities as deforestation, soil erosion, water pollution, desertification, urban blight, and perhaps even climate change. Not many people willfully cut down a fruit tree, and that fact of life could and should be capitalized upon for the common good.

Such possibilities undergird this book's perspective. It is hoped that in the years to come fruits will increasingly contribute to the personal welfare of African peoples. Already, consumers worldwide are demanding ever more fresh produce, further increasing the pressures on, and potentials for, the kinds of plants we describe.

The native fruits have a lot of catching up to do. But that is hardly Africa's own fault. In part or perhaps in main, the woeful neglect reflects international priorities of past decades. Those priorities were not unjustified: Near-miraculous rises in the quantities of wheat and rice in Asia probably staved off as big a famine as humanity ever faced. But a shortage of staples no longer limits most food supplies. The time for "quality foods" has come, and they especially strengthen "subsistence" economies. Being among the highest quality foods, fruits (and of course vegetables, too) seem likely to lead a rising tide of new and improved sustenance for a better-fed humanity.

Nowhere is that trend more important than in the nations whose underexploited resources we describe. And their indigenous fruits offer a wealth of opportunities for progress. Yet the next steps demand neither grandiose government enterprises nor massive international interventions. The advancement of local fruits can be jump-started by community initiatives as well as pioneers who undertake such tasks as:

- Locating superior varieties;
- Developing growth, harvest, and maintenance routines;
- Improving storage, handling, packing, and packaging to improve market acceptability and reduce devastating losses;
- Instituting standards and controls that improve quality, even to the level demanded by exports;
- Increasing individual and institutional awareness;

- Opening supplies to competition, fostering the vital price differentials that induce growers to excel; or
- Developing markets and the infrastructure (physical, legal, and mental) to compete locally and perhaps even internationally.

Of all these steps, the first—locating the best varieties—represents the key. Any undeveloped species tends to produce fruits varying in taste, size, appearance, texture, and proportions (including thick skins, large seeds, and thin flesh). Any undeveloped species also tends to produce fruits varying in horticultural qualities such as disease resistance or response to care and extreme conditions. One of the most vital and rewarding activities is to seek out the individual specimens with the largest number of desirable qualities. With those in hand, selection, clonal propagation, and other horticultural manipulations can quickly transform a plant's prospects for commerce and for national nutrition.[3]

It should not be thought that such advances must be restricted to prestigious researchers or plant-science specialists. Surprisingly few of the premier fruits of the Western world were developed by scholars; most are the products of farmers, horticulturalists, and amateurs.[4] In Africa there is a vast constituency of motivated plant lovers and activists to pursue similar goals. These currently untapped thousands include farmers and growers themselves, amateur horticulturists, village leaders, anthropologists, home economics specialists, doctors and public health professionals, nutritionists, entrepreneurs, missionaries, philanthropists, students, school children, school teachers, foresters, environmental activists, landowners, and fruit-loving citizens of all regions and responsibilities.

Such, then, is the wide audience this book hopes to reach. Furthering the understanding and greater use of native fruits provides opportunities for contributions by people of passion and persuasion, wherever they might be and whatever their place in life. It is especially hoped individuals positioned to help Africa get on its feet will find motivation.

There is, of course, a special place for advanced science in this humanitarian service, starting with Africa's trained agriculturists, for whom these fruits (and vegetables) provide an unparalleled opportunity to advance their regions and their careers. Research is particularly needed for

[3] An example of this is the kiwifruit, which arose as a crop after a New Zealand grower noticed a single plant with double-sized fruits. Before that *Actinidia deliciosa* was a tiny wild berry of China with little future in formal cultivation.

[4] For instance, the current "standard" avocado ('Hass') was discovered by the children of a mail carrier who, in the 1920s, was starting a small grove in the hills outside Los Angeles, USA. Unable to afford trees that were already grafted, he planted seedlings of unknown pedigree as rootstock, and then grafted the then-dominate 'Fuerte' variety onto them all. All the grafts took but on one seedling. He intended to chop it down but his children loved the flavor of its fruits so much he was persuaded to save it and, today, almost all of California's avocado comes from that single rogue seedling of Mr. Hass.

overcoming pests and diseases that suppress yields and destroy or disfigure the harvests. A key problem in Africa, as elsewhere, is that mammals, birds, insects, microbes, and other fruit-lovers seek to consume production before people can. The application of current biological knowledge could greatly boost the production and protection of traditional fruits, yet this is just one pressing and compelling arena: Virtually no aspect of these fruits has been touched by science. The separate chapters identify specific areas for incisive applied research, much of which can be undertaken now, with little cost, by small groups or individuals.

It seems especially noteworthy that the age-old foods described in the chapters ahead also offer practical new opportunities for developing regional cooperation among African states. These plants are a starter to catalyze collaboration in research as well as development, growth, and trade. As such, they should be regarded as a neglected resource for helping all the continent's inhabitants. Africa's "lost" fruits provide the possibility for advancing common interests continent-wide.

Noel Vietmeyer
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LOST CROPS of AFRICA

volume III part 1
Cultivated Fruits

INTRODUCTION

Like Asia and the Americas, the continent of Africa is blessed with a rich tropical flora. Many of the 50,000 or so plants that evolved within its forests and savannas ripen fruits to tempt the myriad wild creatures into spreading their seeds. Speaking generally, Africa has as many of these tasty morsels as tropical Asia or America.

This fact, however, is something one would never guess by looking in produce markets or college textbooks. Today, American and Asian species dominate tropical fruit production worldwide, including within Africa itself.

For this, there is good reason. Africa's fruits have not, by and large, been brought up to their potential in terms of quality, production, and availability. Geographically speaking, few have moved beyond Africa's shores; horticulturally speaking, most remain poorly known. Thus, the vast continental landmass lying between Mauritania and Mauritius contains a cornucopia of horticultural, nutritional, and rural-development jewels still waiting to be cut and polished.

Perhaps it is not strange the world bypassed these fruits. Until comparatively recently, most populations in Africa were disperse enough that fruits—seasonally abundant—could be picked wild without the demands of cultivation under domestication. Further, many African cultures—like many others—regarded fruits less as daily fare than a refreshing snack, child food, or some other kind of non-serious indulgence. Then when mango, banana, citrus, cashew, and papaya arrived from Asia, and then when guava, pineapple, avocado, and passionfruit arrived from America, incentive for advancing local fruit diversity increasingly vanished. In the face of these highly domesticated newcomers, local fruits entered a downward spiral in which lack of respect and neglect led in turn to a progressively greater lack of awareness and knowledge, until Africa's fruits receded into the background. Making matters worse was the reality of recent centuries, as traditional eating habits began to fade—including those incorporating or even depending on local fruits.

It should also be mentioned that the displacement of ancestral foods was not necessarily due to consumer preference. For one thing, compared to the already-improved foreign fruits, Africa's species could seem relatively difficult to select and reproduce, a hindrance to expressing their potential qualities and achieving their ultimate place in the food supply. That feature further turned growers toward the better-known tropical fruits, whose breeding and propagation problems had been already overcome and whose culture could be found in books and colonial expertise. In this light, the

powers who until the last century wielded the purse strings also focused their funds—both production and research—on bananas, pineapple, coffee, cacao, oil palm, and other fruits of proven higher value as export crops.

Thus, although the indigenous fruits described in the following section may be cultivated, most are unknown to the sort of large-scale organized operations that are routine with oranges, mango, banana, or papaya. Instead, they are grown mostly as small or solitary plantings in village settings and home gardens, and are produced more by tradition than horticultural technology. Almost all are raised from seed rather than the vegetative propagation that defines fruits elsewhere. As a result, yields are unreliable and often unrecorded, flavors are variable, and varieties unselected. Soil and fertility requirements remain uncertain, and even propagation techniques in some cases are unknown. In addition, nutritional information is lacking, incomplete, or so based on old or limited analyses it may be representative or may not be. Indeed, it has been said that the fruits of Africa largely persist in forms already recognized generations ago. It could also be said that the management of these plants largely persists in forms unchanged as well.

Regardless of all difficulties and doubts, however, now is the time to rediscover this heritage, to apply the art of horticultural science to African fruits, and to make them work harder. Both the need and the opportunity are nowadays great. The tragic and widespread occurrence of ill health among children is one glaring example why support for Africa's fruits is vital. Without doubt, neglect of nature's own endlessly renewable nutritional supplements contributes to this malnourishment, at least in rural districts. Native fruit resources, measured against communal nutritional needs, seem likely to be of the highest value. They hold promise to become levers for lifting the most nutritionally vulnerable in the most widely scattered areas of Africa. Indeed, fruits make the best of all food supplements. Not only are they appealing to the vulnerable young and old and ill, they provide what might be called "sustainable nutrition."

Moreover, fruits provide their wealth in the locale most needing sustainable nutrition. Every quality-of-life indicator shows the rural poor generally face the worst hardships. Approximately three out of every four desperately poor Africans reside *outside* the cities. And for at least the coming generation, rural inhabitants will outnumber their urban counterparts, even if mass migration to the cities persists.

If poverty's weight falls especially heavily on its rural population, then *rural* development is vital for achieving overall poverty reduction and improvement in African life. And developing Africa's own local fruits is one practical approach to nourishing these local lives.

SUMMARIES OF INDIVIDUAL SPECIES

Following are short summaries of ten notably promising cultivated fruits selected for treatment in this volume's opening section. The potential of these species to confront humanitarian challenges in Africa is addressed in the sections following these summaries, as well as in Table 1 on page 7. This information is drawn from the detailed chapters that follow their Introduction.

1. Balanites (desert date, lalob)

This small tree (*Balanites aegyptiaca*, Balanitaceae) tolerates heat and aridity so well it thrives into the heart of the Sahara. Deep-rooted and very spiny, it produces heavy yields of date-like fruits whose gummy, yellow-to-red pulp is more than a third sugar. Although these sweet treats are eaten raw, they are more commonly used as ingredients in cooked dishes. Some, however, are crushed and converted into drinks. The fruit also yields a kernel roughly matching sesame and soybean in composition, being about half oil and a third protein. To become edible it must be boiled for some time, but then it can be turned into many tasty items, including roasted snacks and a spread not unlike peanut butter.
Climate arid

2. Baobab

Few trees on earth engender respect like baobab (*Adansonia digitata*, Bombacaceae). Millions believe it receives divine power through the branches that look like arms stretching skyward (see the chapter on baobab as a vegetable in Volume II). Its fruits sometimes attain the size of melons, and their tough outer casings enclose angular packets of a strange, sticky pulp. A few hours in the sun dries this semisolid into a free-flowing, soluble powder. The resulting "baobabfruit flour" has a gingerbread flavor enlivened by a not unpleasant acid bite. It is nutritious enough to be stirred into warm water or milk to create a health drink. The fruit also contains nuts with an almond-like taste. Although difficult to get at (owing to a thick shell) the nuts are valued foodstuffs, eaten fresh, fermented, or roasted like peanuts. They are rich in both food energy and quality protein.
Climate tropical

3. Butterfruit (safou, bush mango)

Butterfruit (*Dacryodes edulis*, Burseraceae) may be unknown to the world, but in Central Africa and neighboring sections of West Africa this small tree is an almost universal component of traditional farming. Throughout this broad tropical belt it contributes importantly to nutrition and

farmer income. Like tomato or eggplant, the fruit is mainly used as a vegetable. It has a pleasant smell and attractive appearance and is extremely high in food energy. Indeed, up to two-thirds of the pulp comprises an oil of very desirable composition. In addition, the pulp is one of the best protein sources to be found in the world of fruits. About a quarter of the dry pulp is protein, and it is of superior nutritional quality. To top all that, butterfruit provides notable dietary minerals.

Climate tropical

4. Carissa

Carissa (*Carissa macrocarpa*, Apocynaceae), from South Africa and Mozambique, yields masses of shiny fruits that are often call Natal plums. Their thin red skin covers a pinkish-red, almost mealy, flesh that is flecked with a milky juice. Flavor varies from tart to more or less sweet, depending upon variety and maturity. Even though production is now haphazard and essentially unsupported by the muscle of modern knowledge, carissa promises to become a much greater crop. Even in its present form this fruit has an ample edible portion and, having no stone in the center, it can be eaten whole. These versatile foodstuffs make tasty jams, jellies, and drinks as well as attractive highlights in salads and desserts of all kinds. Some taste like raspberry; most, though, are as tart as cranberry.

Climate subtropical

5. Horned Melon

A spiky orange oddity crammed with green jelly and white seeds, the horned melon (*Cucumis metulifer*, Cucurbitaceae) has gone global in recent decades; New Zealand, Israel, and Kenya are among countries shipping it around the world. Back in its native habitat, southern Africa, the plant is little used, but in a few places—Malawi, for instance—people grow it for sale in the local food markets. Seemingly, its home territories could make much more of this strange comestible, not only as a dessert fruit but also as a vegetable like cucumber.

Climate temperate, subtropical, and semiarid

6. Kei Apple

The shrubby plant known botanically as *Dovyalis caffra* (Flacourtiaceae) produces fruits that resemble little golden apples. Indigenous to the southern zone—including Malawi, Zimbabwe, Mozambique, and South Africa—it becomes bespangled with fruits whose thin, tough skin shelters a yellow, melting, juicy pulp with a lively aroma.

Climate subtropical

7. Marula

Marula (*Sclerocarya birrea*, Anacardiaceae) is prized for its fruits as well as its seeds. Both are in high demand from Cape Verde to the Cape of Good Hope. In some societies the tree ranks as a major food supplier. The plum-sized fruits have a thick yellow peel and translucent white flesh. They can be eaten fresh but most are processed into things such as beverages, jams, and jellies. Although the succulent pulp has a unique flavor, writers struggling for a frame of reference have variously likened it to litchi, apple, guava, or pineapple. The kernels inside the seeds are commonly compared to macadamia nut.
Climate subtropical (the best-known species) or tropical (a separate and lesser known species)

8. Melon

The melon (canteloupe, muskmelon; *Cucumis melo*, Cucurbitaceae) is one of the two African fruits that are known around the world. All the warmer regions produce it, of course, and millions enjoy a melon for breakfast, lunch, or dessert. Today's melons are based almost entirely on seeds carried out of Africa, probably on the backs of camels northward across the Sahara in the time of the Pharaohs. While today India, Japan, and many other countries have greatly improved, locally selected varieties, the full wealth of the species' diversity was not only left behind, it was forgotten, and remains to this day largely untapped. Who knows what kinds of 21st century melons can be developed by finally utilizing the "lost" half of this fruit's heritage?
Climate most climates

9. Tamarind

Throughout the tropics tamarind (*Tamarindus indica*, Leguminosae) provides an attractive backdrop to roadsides, fields, and markets from the East Indies to the West Indies. And everywhere it grows, people enjoy the shade cast by its feathery foliage, not to mention the curiously sweet-sour pulp found inside its brittle, gray-brown pods. What is not widely known is that tamarind is actually from western African. The original wild version, a common savanna tree, can be found over an area stretching from the Atlantic seaboard to the verge of Central Africa's rainforests and east. Senegal's capital is actually named for this tree, which in the local Wolof language is called "dakar." Despite its current spread, this species is far from fully exploited, and it could become an even greater tree in the tropics, notably including countries within the boundaries of its own home continent.
Climate dry savannas and monsoonal regions

10. Watermelon

Other than botanists, few people consider that watermelon (*Citrullus lanatus*, Cucurbitaceae) is indeed African. Yet this crop's wild ancestors are scattered abundantly across the dry wastes of the continent's semi-arid southern hinterland. The ancestral genes to be found in the wild and tended watermelons bespeckling millions of hectares in countries such as Botswana and Namibia seem likely to provide the genetic means for creating new varieties, new seed foods, new pickles, and new types of watermelon fruits with unusual colors, shapes, sizes, and flavors. It is entirely possible that genes from Africa's wild types could soon spark a watermelon rebirth worldwide.

Climate warm-temperate to tropical

TABLE 1: POTENTIAL ROLES FOR SELECTED CULTIVATED AFRICAN FRUITS

*** = ***Outstanding;*** ** = ***Notable;*** * = ***Average***	Overall	Nutrition	Food Security	Rural Development	Sustainable Landcare	PRIMARY OCCURRENCE			
						West Africa	Central Africa	East Africa	Southern Africa
Balanites	***	***	***	**	***	√			
Baobab	***	***	***	***	***	√	√	√	
Butterfruit	***	***	***	***	***	√	√		
Carissa	**	**	*	**	**				√
Horned Melon	*	*	*	*	*			√	√
Kei Apple	**	*	*	*	**				√
Marula	***	***	***	***	***	√	√	√	√
Melon	**	*	*	**	*			√	√
Tamarind	***	***	***	***	***	√	√	√	√
Watermelon	**	*	*	**	*	√		√	√

NB: The underlying justifications for these broad rankings are discussed in the following sections on Nutrition, Food Security, Rural Development, and Sustainable Landcare; greater detail is provided in the separate chapters on individual crops.

POTENTIAL ROLES FOR SELECTED CULTIVATED AFRICAN FRUITS

To give some idea of the potential of these fruits to help solve the great central issues of African economic, health, and environmental development, we now summarize the above-mentioned fruits' likely relevance to four of Africa's biggest needs for human survival and social serenity: 1) nutrition, 2) food security, 3) rural prosperity, and 4) general landcare.

OVERCOMING MALNUTRITION

Although pertinent nutritive information is often poorly available, it can be anticipated that all African fruits are useful sources of nutrients, particularly vitamin C. Indeed, a study of local fruits harvested and consumed in West Africa, particularly Senegal, suggests that they alone can meet year-round vitamin C needs. Of the 29 fruits analyzed, 11 had vitamin C contents higher than 20 mg per 100 g. Many may also be good sources of beta-carotene (provitamin A), usually revealed by a yellow coloration.

Fruits also provide necessary minerals. The often-substantial contents of calcium, phosphorus, potassium, and sometimes iron are of special value to children whose growing bodies desperately need these elements to build teeth, blood, muscle, bone, and brain. Many fruits also provide magnesium, an element critical for cellular metabolism, protein digestion, and proper functioning of the nervous system.

Furthermore, fruits rank high on the recommended-food charts because they provide dietary fiber. Numerous studies indicate that dietary intake of fiber reduces serum cholesterol and is perhaps associated with several other health benefits.

And in the continent's many dry zones fruits, are valued for providing water in a pure form. A melon, for example, makes a valued thirst quencher—not to mention natural survival kit—for people crossing deserts or working in hot fields.

Finally, it can be said that fruits are beneficial not only for what they provide but for what they don't. They contribute, for instance, no cholesterol and typically have only tiny amounts of fat.

Below is a summary of the merits of the fruits highlighted in this section, *specifically in terms of fighting malnutrition*.

Balanites (desert date, lalob)

Children like the sugary balanites fruits, and throughout the species' range these are widely consumed by the young. This makes it a key to malnutrition reduction in the vast, parched, and perilous arid zone where few other useful plant species exist. The pulp contains carbohydrate (notably

sugars), protein, a smidgen of fat, and undoubtedly notable levels of vitamins and minerals. In addition, the seed kernel is rich in both an oil of the desirable unsaturated type and a protein whose amino-acid quality almost matches that in peanut. The pulp and seeds, separately or together, are thus excellent dietary means for assisting the malnourished, both young and not so young.

Baobab

Nutritionally speaking, the strange chalky powder from a baobab fruit can be considered nature's gift to natural food fortification. The dry, soluble flour provides a simple way to add protein, carbohydrate, energy, fiber, provitamin A, vitamin C, several B vitamins, calcium, phosphorus, and iron to other foods even in remote areas where delivering those by other means is difficult. Moreover the protein has an excellent amino-acid profile, including good quantities of such essential vegetative rarities as lysine, methionine, cystine, and tryptophan. At least in principle, this seems like a readily available homegrown means for reducing malnutrition on a long-term and large-scale throughout much of Africa.

Butterfruit (safou, bush mango)

Packing a combination of protein and energy, butterfruit pulp is promising for reducing Africa's worst humanitarian problem, protein-calorie malnutrition in children. Although presently unreported in nutrition programs, it might prove a lifesaver for children, nursing mothers, and the desperately malnourished. Its protein contains levels of essential amino acids similar to those found in eggs, milk, and meat. Moreover, the oil making up roughly half the pulp is composed mainly of desirable unsaturated fatty acids. And beyond protein and edible oil, this fruit provides an array of minerals such as potassium, calcium, and magnesium. Clearly, this fruit possesses the nutrient power to counteract what is currently the most common form of malnutrition.

Carissa

Although generally eaten for pleasure rather than health, carissa nevertheless packs some nutritional wallop. Indeed, it contains somewhat more vitamin C than the average orange and enough calcium, phosphorus, and magnesium to designate it a fine source of minerals. The red pulp looks and tastes so good it is often added to sick-people's foods to entice them into downing pasty-colored porridges. The fruits are also dropped into water bottles and gourds to liven up the liquid contents. For these and other features carissa could be a good delivery system for the very nutrients everyone needs and not everyone gets.

Horned Melon

The nutritional value of the horned melon's flesh is low, and the seeds are poorly known. The fruit seems unlikely in its present form to make a major dietary contribution against malnutrition.

Kei Apple

Kei apples are highly acidic for the simple reason they have more vitamin C than oranges. Beyond that, little of their food value is known. This fruit's value in nutrition programs is certain to be good but not necessarily good enough to warrant special effort on those grounds alone.

Marula

Although an important source of several nutrients, marula fruit stands out for its vitamin C. In this regard, the flesh commonly surpasses orange, grapefruit, and lemon. Add to that macadamia-like nuts, possessing protein, an edible oil ranked with the elites, and minerals such as calcium, magnesium, and phosphorus, and you have a nutritional powerhouse borne by a widespread plant seemingly created for today's needs.

Melon

Dietarily speaking, most people consider melon a sugary nothing. But it provides potassium, vitamin C, and almost as much provitamin A as mango.

Tamarind

Tamarind pulp is a good source of the B vitamins thiamin, niacin, and riboflavin as well as phosphorus, potassium, and calcium (whose content is reportedly the highest found in any fruit). There are claims that tamarinds are also high in iron, which could make them useful anemia preventatives. The fact that kids love sucking on these not-so-pretty fruits means this long-lived and highly adaptable tree could be a significant nutrition-delivery tool. Plant tamarinds beside the tracks to school and you'll likely feed generations of children and, in addition, leave a legacy of shade for the society and soothing scenery for the ages.

Watermelon

Although no one eats watermelon for medicinal purposes, the contents of carotenoids—especially beta-carotene and lycopene—are substantial. Watermelon also is a significant source of vitamin C and fiber. As for minerals, the fruit supplies potassium and is at the same time very low in sodium. It also provides a safe liquid refreshment for washing down a meal.

BOOSTING FOOD SECURITY

The words "food security" signify the concept of access to sufficient food all the time. The principle is as important as ever because all-too-often a steady supply is thwarted, not just by poverty but by conflict or natural events. So it is for good reason that societies rely most heavily on staples, whose dry skins and starchy hearts make them easy to ship, sell, and store. This "always-ready" keeping quality supports everyone's continuing need for food. However, when supplies of staples get shaky, people naturally turn to the wider variety of edibles around them. And many of these are fruits that grow on trees.

It may come as a surprise that Africa's native fruits *can* help hungry stomachs fight back. Though we rightly think of fruits as having nutritional punch, many also pack proteins and carbohydrates. Such combinations have often staved off starvation until staple supplies could stabilize.

Below, we summarize the merits of the fruits highlighted in the book, *specifically in terms of food security*.

Balanites (desert date, lalob)

Balanites produces a wealth of resources where other plant life barely survives. A plunging taproot makes it drought resistant, thick bark helps it survive the ubiquitous grass fires. It also tolerates inundation, wind, sandstorms, shallow and compacted clays, salt spray, soil salinity, and termites. It would thus seem to make an ideal security shield for the food supply in an area where such hazards all too often decimate other food resources. And it is not just the fruits and seeds that save lives. In times of extreme famine, the flowers, leaves, and even bark become sustenance for people. Moreover, the seeds are so popular as animal feed they underpin livestock production in dry places and in droughty seasons when even goat and camel husbandry operates at their outermost limits.

Baobab

Perhaps this fruit's most vital humanitarian use is in feeding those who cannot buy their way out of starvation during the hungry times. For this purpose, the pulp of baobab fruit is beaten into thin pancakes, which on exposure to the sun dry into hard, brown disks. Despite the disconcerting look of leather, these are immensely valuable in that they can be stacked up like dinner plates and stored away in a corner for months or even years. Poor people in a dozen countries rely on this reserve during droughts or other disasters when neither gardens nor markets yield adequate provender. And during famine times they also rely on baobab seed, a compact package of energy, protein, and micronutrients. This strange tree even supplies water to the thirsty. At the height of the rainy season villagers in parts of Africa prize

open a bunghole in the bark and fill the hollow interior with water. Thanks to natural preservatives, the water stays potable, and during the subsequent rainless months it saves lives.

Butterfruit (safou, bush mango)

This species seems likely to provide a superb means for ensuring food remains on hand during difficult times. Even now, the trees exist in countless villages and contribute to mass welfare in some of the hottest, most humid, and harshest of all agro-climates. By helping people survive the annual hungry season—the time when the old crop is gone and the new one is still growing—butterfruits provide the most basic kind of life insurance.

Carissa

Although in South Africa carissa hedges provide generations of kids the micronutrients they need, for the rest of Africa the fruit seems to have little food-security merit, at present.

Horned Melon

Of all the world's fruits, perhaps none has a better shelf life than horned melon, which can remain edible for 6 months even in the tropics. On the other hand, this peculiar fruit can be a challenge to store. Its spikes can stab neighboring fruits, opening them up to decay and ruin in days. They also contain little food energy. Overall, we see no particular Africa-wide food-security use for horned melon without further nutritional development.

Kei Apple

This robust, tolerant shrub can produce fruit during times of climatic stress. However, as of now it is neither widely known nor widely loved, and seems to possess little particular food-security significance for the continent at large.

Marula

Unquestionably, this great and treasured species has the potential to help build a line of defense against dietary insecurity. Marula provides food during the season when grain stocks have run low and other crops have yet to attain an edible state. Also, its nuts store so well they provide nutritious sustenance long after all else is gone. Throughout the plant's range, and especially where cereal crops are unreliable, villagers pile up marula seeds for food emergencies. Because of their fine taste, marula nuts are deemed a delicacy, but their fat, protein, and mineral contents make them a crucial food supplement during periodic drought or the annual hungry season.

Melon

In practical terms, there seems no particular food-security merit inherent in the ephemeral melon, which produces its flesh during the seasons of plenty; the seeds of certain types, however, have served as long-lasting provender in the past.

Tamarind

Although its may appear to be quite a minor food crop, tamarind has been called a tree of life because its fruits can be stored away without refrigeration and safely served weeks or months later. They become especially important during the dry season when fresh foods are scarce or nonexistent. Fulani nomads, for example, preserve tamarind pulp in the form of sun-dried cakes, which provide sustenance while they traverse the Saharan sands. This is a simple procedure that perhaps millions throughout Africa could exploit for food-security benefit.

Watermelon

In Africa's southern deserts the undomesticated and casually cultivated watermelons are an important source of both food and water. In times of drought African farmers have traditionally relied on them for emergency use. Sometimes wild fruits scattered across the desert become the sole source of moisture for their cattle—and even for themselves—for months on end. Moreover, people also pile the fruits up near their dwellings as a convenient cache of food and water. These ancestral watermelons remain edible and "potable" a surprisingly long time—up to a year has been recorded for some types.

FOSTERING RURAL DEVELOPMENT

For purposes of relieving rural poverty, fruits are powerful tools. They bring relatively high prices, can be produced efficiently on a small scale, and are among the poor's few natural treasures. For some rural Africans, there is perhaps no better way for achieving a modest income than through the production and marketing of fruits and fruit products. Many species are already grown at home and sold nearby; children also collect fruits to sell within their village. Nevertheless, supplies now reaching the cities mostly fall far below what could (or should) be marketed, and fruit consumption remains low throughout the continent, averaging less than half the amount eaten by Europeans and North Americans, for example—and far lesser amounts among the neediest.

For farmers, as for anyone with access to land, fruits provide an easy entry into the world of commerce as well as into at least the prospect of a reliable livelihood. The food and beverage industry searches constantly for new flavors, so Africa's fruits offer an opportunity that should be taken advantage of...perhaps comparable to cacao (chocolate), of which smallholders are often the major producers. Fruit-based foods and drinks can emerge from small processing factories—most likely situated close to the growing region (because of the costs of transportation and the likelihood of spoilage). Products might include juice, juice concentrate, puree, paste, dried fruit, canned products, and so forth. Successful fruit crops can also bring broad benefits by creating a ripple effect on the economy, raising the standard of living, keeping enterprising youth from fleeing the farm for the cities that beckon so insistently, and raising the tax revenues that result from general commerce.

Below we summarize the merits of each of the 10 cultivated fruits highlighted in this book's first section, *specifically as they relate to rural development*.

Balanites (desert date, lalob)

The middle of the Sahara is not the place to expect to reap profits on any grand scale. However, balanites could provide the basis for small industries that are otherwise inconceivable in the terrain where it grows. The seeds supply a quality vegetable oil that is a prized ingredient in foods as well as in local cosmetics. They also supply a raw material from which certain pharmaceuticals can be derived. In addition, the wood may be of small diameter, but it is highly prized for cooking because it burns almost without smoke. And, although outside the scope of this study, most parts of the plant are considered to possess various medicinal properties.

Baobab

Possibly, there is no better long-term answer more basic or more beneficial to meager rural lives than this ancient food resource. Baobab fruits even now help underpin rural commerce. Each day in West Africa, for example, they leave the countryside by the truckload, bound for the urban markets and for conversion into a popular drink sold in roadside stands as well as supermarkets in countries as far apart as Kenya and Mali. Such markets also proudly display sweets crafted from baobab pulp. Children commonly peddle these colorful candies to the public, and many an entrepreneur began her career selling baobab treats to friends and passersby for pocket money.

Butterfruit (safou, bush mango)

Butterfruit, too, is already a cash crop. Its fruits pour into cities and rural markets in considerable quantities. In the hot and humid zone stretching from Eastern Nigeria to Angola it is common to see women offering these fruits for sale. The tree is an excellent candidate for greater commerce. It has particular promise around the farm and the rural home because it provides so many useful byproducts—among which are forage for the animals, wood for cabinetmakers, and a scented resin that burns with a bright flame. There is also the promise of supplying industrial markets with oil. Both pulp and seeds contain large amounts of a vegetable oil whose qualities make it highly saleable for cooking and cosmetics. Although this oil is not now produced in any quantity, there are signs that larger scale production could be profitable.

Carissa

In South Africa carissa fruits are already commercial resources. Prized by one and all, they sell in considerable quantity in cities such as Durban. An added potential is probably to be found in processed products. Carissa jelly, made by straining or sieving the stewed, slightly under-ripe fruits and cooking them with sugar, is considered among the finest in Africa. It is now gaining aficionados in California and Florida as well. A boiled sauce, whose tang is reminiscent of the cranberry sauce beloved by Americans, is sometimes prepared. If cranberry can make it into the realm of commerce, carissa can too. Indeed, some carissa devotees wouldn't serve anything else.

Horned Melon

At first sight this would seem the least likely resource for rural development. The fruit seems uncommonly undesirable. Yet when New Zealand shipped the fruits to Japan in 1984 they sold readily and aroused intense curiosity. They were soon also exporting them to the United States,

and now horned melon is grown in many countries. Both Kenya and Israel export them to Europe and, nowadays, they are also transported by the container load across the Pacific. While such efforts demand considerable technology, making this seem a case where a lowly crop has a future *only* as a high-tech export, others believe horned melon may well serve as both a fruit and a vegetable that finds ready local markets as well.

Kei Apple

In the past, the sourness of even the ripest kei apple seemed a barrier to the crop's wider acceptance. But in today's markets, fruits need not be sweet to be successful. Cranberry, as we've said, is bitingly sour and is increasingly used for that very reason. Kei apple gives a bite (and color) to drinks, candies, jelly desserts, and many other food products.

Marula

This seems an excellent vehicle for rural development. Considerable demand already exists for both the fruits and the nuts. In Namibia, Botswana, Zimbabwe, and South Africa, a rising number of operations are being established to process marula fruit, some handling over 1,000 tons a season. The pulp is appearing in mainstream commerce in the form of juices, jams, jellies, puree, and liqueur. Oils are being extracted from the nuts and put into pricey products for the skin, a process pioneered in Namibia, which now exports marula oil for this purpose. Processing marula materials can offer help for some of society's most needy. Shelling the nuts, for instance, provides work for thousands of rural women who have hardly any other source of income.

Melon

Melons are reasonably priced and some have been bred with rinds robust enough to handle overseas travel. The scope and complexity of flavors, sizes, flesh colors, and textures makes melon one of the most interesting fruits. And it is more popular than most people think. In the United States, for example, melons are second only to bananas as the most-consumed fresh fruit per person. Moreover, melon could have a far greater future in commerce, especially given all the biodiversity still untapped in the vastness of Africa. There may also be markets for its seed as well. This is not a new idea: Sudan once exported tons of "senat" seeds annually, with only cotton, sorghum, and sesame earning more revenue some years.

Tamarind

This species has promise for boosting rural development in most parts of the tropics. The pulp is a versatile food that can be mixed into the myriad

different sauces and drinks favored in the equatorial lands. Its tang especially blends with the fire of chilies, a marriage lending many tropical dishes their distinctively tart, sweetly biting savor. Certain African countries have been advancing this as a commercial resource. In Mali and Burkina Faso, for example, tamarind-based drinks (both fresh and carbonated) rival world-famous soft drinks in popularity. And the locally produced tamarind-syrup concentrate is said to outsell the fancy fruit syrups France exports to Mali. The country is itself exporting tamarind syrups to Europe, where they are sold on the streets (not to mention the bars) of Paris and Rome.

Watermelon

Watermelon fruits are generally easy to grow and easy to sell. They would seem to offer prospects for rural development anywhere they can be cultivated. The seeds are also saleable. West Africa already exports them to France for snack food. Sudan does too. (These seeds, which commonly go by the name egusi, are dealt with in detail in Chapter 8 of the companion volume on Africa's vegetables.)

SUSTAINABLE LANDCARE

Trees and shrubs that yield edible products could be a key to establishing environmental stability from the Sahara to South Africa. They incorporate the very essence of sustainable agriculture. Seen in this light, fruit trees are among the most promising tools for securing agricultural systems that are both long lasting and gentle on the land. Benefits from growing fruit crops—especially perennial ones—include:

- Lessening soil erosion. The trees' roots and surface debris help reduce loss of topsoil and runoff, thereby maintaining soil fertility and slowing siltation of rivers, dams, irrigation systems, and other waterways.
- Lowering soil temperatures. Dense foliage absorbs about two-thirds of the sun's rays, while reflecting and transmitting the remainder, so that within the tree-shaded microclimate temperatures are lower, the light less damaging, and the site more stable and sustainable.
- Increasing organic matter in the soil. Leaf litter and decay add to the nutrients, tilth, stability, and productivity of the land.
- Breaking the wind. The physical presence of a cluster or even a scattering of trees reduces soil loss and improves the microclimate for other growing plants for the simple reason that wind is broken up so it is less likely to desiccate or disturb the soil.
- Supporting beekeeping. Fruit trees are, generally speaking, good sources of nectar and pollen. Their very presence therefore can produce income from honey, wax, and related beehive products. Honey also makes a good dietary-energy supplement, especially where foods are bland or the diets short on food energy.
- Reforesting the land. Tropical fruit trees are an element in reforestation that has been largely overlooked. The fact is that people everywhere like fruit trees, and will plant them and protect them because the trees generate blossoms, food, and funds. This is especially important for the future of Africa, where this interest could be the key to persuading the populace to plant trees.
- Earning carbon credits. For purposes of "global cooling," what could be better than trees that feed the hungry as well as provide all the benefits mentioned above? Fruit trees (together with the soil beneath them) are long-lived carbon sinks that local people respect and protect for generations.

Summarized below are some likely contributions of Africa's cultivated fruits to *sustainable landcare*.

Balanites (desert date, lalob)

Balanites offers ways to help address pressing environmental problems in perhaps the most drought-afflicted area on earth. Beyond the humanitarian benefits deriving from its fruits and seeds, balanites could help overcome

desertification, avoid soil erosion, and reduce the land destruction caused by cattle. The living trees themselves provide shade from the burning sun, shelter from the hot winds, and relief from the never-ending starkness of the desert all around. All in all, it helps stabilize both human life and the natural environment in these severely challenged regions.

Baobab

The tree may be tricky to plant, slow to mature, and susceptible to grazing, but once established it is nearly indestructible. The trunk soaks in water like a sponge, making it resistant to the grassfires afflicting the savannas each summer. Once past its juvenile susceptibilities, a baobab provides its multiple environmental benefits to successive generations.

Butterfruit (safou, bush mango)

In agroforestry and landcare, this versatile species also has promise. It is often seen scattered in riverbeds, across hillsides, and along the boulevards. Possibly it has potential in plantation forestry. The timber, although small in diameter and short in length, can substitute for mahogany. Its woodworking qualities and interesting appearance suit it to veneers and fine cabinetry.

Carissa

Various types of this bush are used for property boundaries, screens, ground covers, landscaping accents, barriers against intruders (two legged and four legged), or container plants. Carissa is also espaliered against a sunny wall or pruned into small trees to beautify a backyard. Few plants are more decorative, tough, or adaptable. The clean and shiny look of the stiff, bottle green leaves makes the shrubs handsome year-round, and the fragrant flowers and crimson fruits lend added beauty.

Horned Melon

In this species, we see no particular value for long-term protection of Africa's soil and environment, though we could be proved wrong. Interestingly, the vines wither at the end of the rains, but the fruits continue to ripen and persist long into the dry season, often serving as a water source.

Kei Apple

This tough shrub does well in almost any soil, including limestone. It is extremely drought resistant and tolerates salinity and even ocean spray. For this reason, for example, it is used as a windbreak or ornamental in coastal California. Its long sharp thorns deter both people and animals. It is commonly seen in hedges and it has been formed into rough rural corrals in southern and eastern Africa. In some climates the untrained plant takes on a

rather scraggly appearance, but it still makes an excellent hedge. Being evergreen, it provides a year-round screen.

Marula

A fully grown marula tree is large and spreading. People genuinely like it for its shade and beauty, not to mention having the fruits to eat. When farmers clear land, these trees are often all that is left standing. Marula thrives under exceptional heat. And it tolerates some of the most inhospitable terrain known to horticulture. Its value for environmental improvement could be outstanding.

Melon

Melon may offer no particular landcare virtues except as a seasonal groundcover, also containing minerals the deep roots pull to the surface.

Tamarind

The living tree is especially promising for restoring deforested and damaged lands to health and productivity. It is already used in anti-desertification programs because it grows in arid and other challenging sites, and it resists savanna groundfires. Rows are also planted among forest trees as firebreaks. Tamarinds probably have notable value for sequestering carbon because people hate cutting them own, and they are so tough they typically grow for centuries. Thanks to a deep and extensive root system, they are little affected by typhoons and cyclones. They withstand city smog and coastal salt air. A dense crown of drooping branches bearing feathery foliage makes this evergreen outstanding for beautifying parks, backyards, boulevards, markets, country roads, and the rest. For these reasons and more, it holds much promise in African reforestation, especially for plantings in places where people live, work, congregate, and revere good shade.

Watermelon

Like its cousin, the melon, it seems to offer no particular long-term landcare benefits or hazards, though its watery fruit in the wild can provide moisture to grazing wildlife long into the thirsty season, thus sustaining the animals that shape entire landscapes.

* * *

The above summaries have highlighted the benefits that may accrue from a broader appreciation for Africa's cultivated fruits. The abstracts were drawn from the detailed chapters that follow, where information is also offered on obstacles to fruition (few of which seem insurmountable).

DESCRIPTIONS AND ASSESSMENTS OF INDIVIDUAL SPECIES

Balanites aegyptiaca Del.

1

BALANITES (Desert Date, Lalob)

It is hardly surprising that balanites (*Balanites aegyptiaca*) is exploited; what is truly surprising is that it isn't exploited more.[1] This small, deep-rooted tree tolerates such heat and drought that it thrives in the heart of the Sahara, and is common in places such as Tamanrasset, Algeria and Kordofan, Sudan. It is, moreover, exceptionally useful.[2] Indeed, it has so many useable parts and products that a proverb in the Sahara runs: "A *bito* (balanites) tree and a milk cow are just the same."[3]

Among other things, these very spiny trees bear heavy yields of fruits—as many as 10,000 annually on a mature tree in good condition. The gummy, yellow-to-red pulp of these date-sized morsels contains about 40 percent sugar. It is sometimes eaten raw, but is more commonly converted into drinks, cooked foods, and medicines.

The seed extracted from within that pulp yields a tasty kernel. Rich in protein and oil, this almond-shaped nut has perhaps more potential than the date-like flesh around it. In gross composition, it is something like sesame seed or soybean—about 50 percent oil and 30 percent protein. To become edible it must be boiled for some time, but then it can be processed into various tasty snacks, including roasted nuts and a spread that looks and tastes not unlike peanut butter.[4]

The tree provides other useful resources, too. In times of famine, the flowers, leaves, fruits, and even bark are relied on for food…indeed, for life itself. The seeds are always popular with animals, and they underpin

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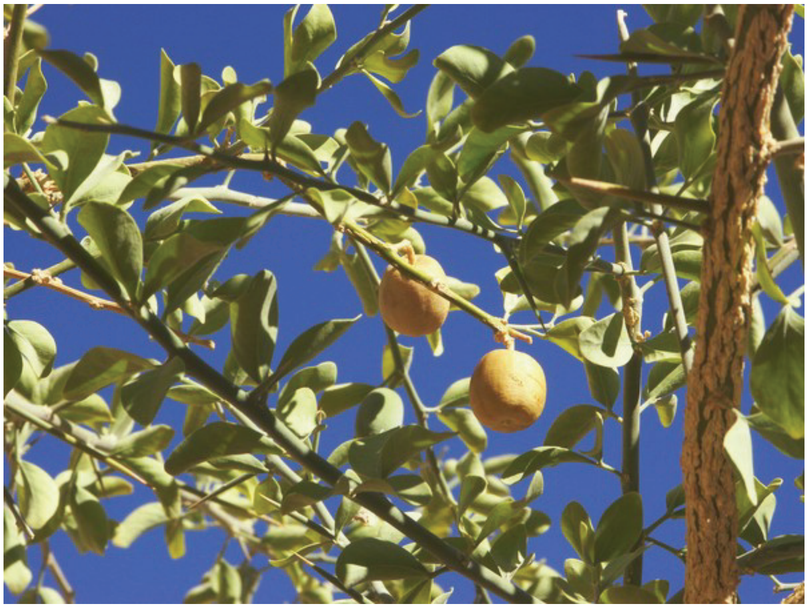
[1] We choose to call this fruit "balanites" (pronounced bal-an-EYE-tees or bal-an-IT-ees) only with reluctance. It is normally called "desert date" in English, but that name is confusing because the plant is not the common date, which certainly grows in deserts but comes from a palm. Lalob, the Arabic name, is used throughout the Middle East but is unknown in most of Africa.

[2] Strictly speaking, this is an undomesticated plant. We include it among cultivated fruits because in most Sahelian nations it is planted by farmers or stockbreeders. Moreover, it is planted for dune stabilization and other environmental purposes.

[3] This was recorded in what was once called Bornu, a region now mainly found in northeastern Nigeria and Chad.

[4] In a survey 3,000 people judged this "balanites butter" to be "tasteful, with good smell and high quality."



Balanites produces heavy yields of date-like, bittersweet fruits whose gummy, yellow-to-red pulp contains about 40 percent sugar. Although these sweet treats are eaten raw, they are more commonly used as ingredients in cooked dishes. Some are crushed and converted into drinks. The fruit also yields a nut roughly matching sesame and soybean in composition. (András Zboray)

livestock production in dry places and in drought seasons where animal husbandry reaches its outermost limits. The wood is highly prized for cooking because it burns almost without smoke. Oil from the seed is a prized ingredient in local cosmetics. Twigs plucked from the branches are used to clean the teeth. The living trees themselves provide shade, shelter, and blessed relief from the never-ending starkness of the desert all round. And the fact that the older plants have razor-sharp spines is put to good use in hedges around houses and kraals around animals. Finally, most parts of the plant are considered to possess various medicinal properties.

Considered in fullest perspective, balanites produces a wealth of resources where other plant life can barely survive. Its deep taproot makes it drought resistant. Its thick bark helps it resist grass fires. It also tolerates termites, seasonal inundation, winds, sandstorms, shallow and compacted clays, salt spray, and soil salinity.

If, as is generally believed, humanity began in Africa, then the bittersweet balanites fruit is likely among the oldest of all foods. Certainly, this resilient evergreen has been helping people out for thousands of years. Its fruits have been found in pharaohs' tombs dating back to at least the 12th

dynasty in ancient Egypt. Thus, even royalty has appreciated it 4,000 years.

For all its age-old history as a resource, this is still a "lost" crop. Balanites is seldom, if ever, included in textbooks or monographs of African food production. It is practically unknown to horticultural science. And a concerted effort to develop its true potential using modern capabilities has yet to be attempted.

That situation should be changed. This species produces the necessities of life in one of the world's most difficult zones of existence. It helps stabilize life and environment in the most severely drought-challenged regions. Its native range extends through the hottest and driest parts of the continent: from the Atlantic coast at Mauritania and Senegal to the Red Sea at Somalia, Sudan, and Eritrea. It also extends onwards and eastwards beyond Africa, through the Arava Valley in Israel and Jordan to the Arabian Peninsula, Iran, Pakistan, and India (notably the Thar Desert).

This is not a rare plant. Throughout this vast, parched, and perilous region, scattered balanites can even now be found—and some occur in large concentrations. In Sudan, for example, the species makes up about one third of the total tree population in the country's central provinces; Blue Nile Province alone is estimated to have a million *lalob* trees.

And people like balanites. Throughout its range the fruits are eaten (especially by children, not to mention camels, goats, and wildlife). Although each fruit may look and feel something like a date, it is usually stringy, bitter, and thin-fleshed. Certainly at this stage these fruits lack the date's general appeal. Nevertheless, they should not be written off as some sort of fake date. Far from it. This is a fruit with potential to reduce malnutrition and to underpin food security in the ultimate torrid zones where there are few other useful plant species.

Balanites can also contribute to the reduction of rural poverty. Indeed, it might provide the basis for small industries otherwise inconceivable in the terrain where it grows. For one thing, the seeds could supply food-grade vegetable oil. The golden-yellow liquid is easily pressed out of the kernel and it is both stable and capable of meeting international food standards. For the world at large, a new oilseed may seem of no consequence, but in the seared savannas and desolate drifts where balanites thrives a locally produced high-energy food could be of outstanding importance.

Moreover, the kernels are a raw material from which pharmaceuticals can be derived. The seedmeal (the solid remaining after the oil is removed) contains diosgenin, a raw material for the production of steroids. The world's craving for steroidal drugs—cortisone, birth-control pills, estrogen, anti-inflammatory agents, and many others—is strong and getting stronger. In this regard, alone, balanites might provide a new export for countries that, perhaps more than any on earth, need a source of foreign exchange. The trees are so common that Sudan alone could—at least in theory—produce 1,200 tons of diosgenin, which is enough to satisfy half the world's demand.

All this untapped promise is what makes the fact that balanites is not better known and better developed so surprising. Of course, indigenous people appreciate it…their lives can depend on it. Scientists, though, have given it only scanty scrutiny, and national and international authorities have accorded it little organized support so far.[5]

As the world turns its gaze ever more intently on desert trees in a search for potential foods and sources of income, it will see in balanites ways to help address several of the most pressing humanitarian environmental problems for perhaps the most drought-afflicted area on earth. Balanites offers fruits, seeds, oil, and shade from the burning sun, but it also could help overcome desertification, avoid soil erosion, maybe thwart parasitic disease, and reduce the environmental destruction caused by livestock. Such possibilities are highlighted below.

PROSPECTS

A balanites tree is slow growing and its fruits are far from first class (when compared with the world's top fruits, that is), but its combination of benefits makes it one of the most promising friends to humanity in a vast region where no truly great fruit species can grow.

Within Africa

Although a very adaptable species, it is so little studied that the future is largely guesswork. The following, however, seem reasonable estimates.

Humid Areas Poor prospects. This thorny, irrepressible tree is a potential menace in well-watered regions, a zone that doesn't need it anyway.

Dry Areas Excellent prospects. Balanites has great untapped potential, even though it is already one of the most widely employed species in the vast droughty stretches of sand, stone, and savanna extending from Senegal to Somalia and from Sudan to southern Africa.

Upland Areas Unknown. Balanites is generally considered a lowland species. However, it occurs at altitudes up to 1,500 m in East Africa and 1,800 m in Konso, a region of Ethiopia where rainfall is under 650 mm and extremely erratic. In Algeria's Ahaggar—a region commonly described as "the navel of the Sahara"—it occurs at altitudes up to 1,800 m, with populations of around 30 trees per hectare.[6]

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[5] This is not to slight early pioneers who championed this species. These include French botanists such as A. Chevalier and A. Aubreville who worked in the Sahara during the 1930s. Also, a research team of the United Nations Industrial Development Organization (UNIDO) made special pleas for balanites development in Sudan in the 1980s.

[6] Information from Brama Traoré.

Kanem, Burkina Faso. The small, deep-rooted, very spiny balanites tree tolerates heat, drought and blazing sunlight so well it thrives in the heart of the Sahel. The living trees provide shade from the burning sun, shelter from the hot winds, and blessed eye relief from the starkness of the desert. In times of famine, the flowers, leaves, and even bark provide sustenance. It would thus seem to make an ideal security shield for the food supply in an area where such hazards all too often decimate other food resources. Moreover, the seeds are so popular with animals that they underpin livestock production in dry places and in droughty seasons when animal husbandry operates on its outermost limits. (Laure Guerrini)

Beyond Africa

This plant is already widespread in the Arabian Peninsula, Iran, and much of South Asia. Here its prospects are as good as in the Sahara and Sahel. Beyond these Middle East and South Asian regions, however, this potentially invasive tree should not at present be introduced.

USES

As mentioned, balanites is a plant of many parts and many products. They include the following.

Fruits The ripe fruits are eaten raw or sun-dried and can be safely stored like dates. Some provenances are sweet, others bitter. People (and not only little ones) chew them as snacks. Commonly the sweet pulp is macerated in water to create a tonic, which is also fermented into forms that are more potent. The juice is also often mixed into porridges to liven up the flavor and add a touch of sweetness.

Seeds Today most of the seeds go unused, but in certain areas they are gathered in quantity. After soaking and sun drying, they can be safely stored for months. Subsequently, the kernels are extracted. Roasted, these balanites nuts have an enticing aroma and are typically added to soups and to the various cereal products that are enjoyed in Senegal, Nigeria, Chad, Uganda, and Sudan. The Shuwa in northeastern Nigeria, for example, commonly eat them this way. And to some Shari and Chad peoples these seeds are so important they are the foundation of everyday life.

Seed oil The seed's kernel can contain up to 60 percent of an almost tasteless oil. Sometimes called *zachon* or *betu* oil, it is highly prized especially in Sudan. The culinary properties are comparable to those of a quality vegetable oil. In a recent market survey, for instance, consumers rated it with cottonseed oil for flavor and cooking qualities.[7]

Resin When the bark is damaged, balls of resin form around the wound. The gummy exudate is soft, sweet, and pleasantly chewable—not unlike chewing gum. People deliberately slash the bark in a process reminiscent of inducing rubber from a rubber tree or gum Arabic from *Acacia senegal*. Collected from fresh wounds, the globs are full of fluid and pleasant to suck like sweets. Some are made into drinks; others used as glue.

Flowers This is one of the African plants whose flowers are widely eaten. In parts of West Africa boiled balanites flowers (called *dobagara*) are added to couscous, often at ceremonial meals. They are also eaten with *dawadawa*, a fermented cheeselike food prepared from locust beans (see companion volume on vegetables). The flowers provide important forage for honeybees. Children suck the nectar, too.

Leaves Young leaves are eaten, but only after thorough cooking (like spinach).[8] Commonly, they are boiled and added to crushed peanut balls or to sauces or relishes. They are widely used in sauces in Burkina Faso, where the balanites is considered a dependable famine food.

Forage The leaves are also valued for feed, especially as they remain available deep into the dry season, when grasses and annuals have withered. All types of stock relish them, but cattle and sheep, repelled by balanites' spines, restrict themselves to the young shoots or suckers, which have tender spines, much protein, and relatively little fiber. The plant becomes especially important in times of drought, when animals have difficulty finding anything to eat. Indeed, seen in profile, the trees are usually jagged and lopsided from people hacking at them for feed. Locals are skilled at gathering the maximum foliage while stopping just short of killing the tree.[9] Wildlife

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[7] A contributor from Sudan wrote to us, saying "I prefer it over cottonseed oil and consider it equal to [peanut] oil."

[8] How widely this occurs is uncertain, but it has been reported at least from Niger, Burkina Faso, and Ethiopia.

[9] Balanites leaves reportedly have high protein content. Goats and camels, unfazed by the thorns, browse young branches. Shepherds climb trees and pollard branches for their herds to feed upon, particularly during summer months. One contributor wrote: "In Konso (Ethiopia), balanites is one of the prominent fodder trees planted 'at random' in the fields for fodder, for soil erosion protection and for shade, as well as for the fruits." The combination of camels and this tasty, nutritious desert tree is particularly powerful.

devours the young leaves, fruits, and even the thorns. In particular, giraffes crop the top close.

Kernel Cake The seedcake left after the oil has been extracted from the kernels is nutritious enough to replace cottonseed cake in animal rations. This residue is promising as a locally produced "concentrate" for what are perhaps Africa's driest and least accessible regions. It is high in protein (37 percent) and low in fiber (6 percent).[10] It could prove economically important for much of Sahelian Africa.

Wood Even the unlopped tree is hardly shapely. It is short, and the often-crooked bole is seldom longer than 2.5 m. Despite this, heartwood is useful. It is attractive, easily worked, fine grained, durable, and resistant to insects, including termites.[11] It is made it into bowls, troughs, tool handles, walking sticks, gunstocks, cabinetry, plows, other farm implements, furniture, and mortars and pestles.[12] It is particularly sought for specific parts of camel and donkey saddles. And it is especially valued for fuel because it not only burns with little smoke but also yields charcoal of high energy content.

Shells Every ton of whole fruit yields half a ton of woody shells. These shells are hard, dense, and highly combustible. They make good fuel as well as good charcoal and particleboard.

Spines In West and East Africa people often pile the branches together to form thorny brushwood barriers. They also grow living fences by planting balanites root cuttings in a row. After a few years—if initially protected from camels, goats, and fire—this process forms a hedge strong enough and spiny enough to keep out most two-legged intruders, all cattle, and most goats (except the famous "climbing goats," which are too clever by far). It is especially suitable for cattle kraals.

Extracts Extracts of fruit and bark, while harmless to mammals, kill the snails that schistosomes require as intermediary hosts. They also kill this much-feared parasite's free-swimming life forms as well as the water flea that harbors guinea worm (dracunculiasis), a serious disease in West Africa.

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[10] O.A. El Khidir, A.Y. Gumaa, O.A.I. Fangali, and N.A. Badir. 1983. The use of *Balanites* kernel cake in a ration for fattening sheep. *Animal Feed Science & Technology* 9:301-306.

[11] Careful selection is important here because the sapwood is difficult to distinguish from the heartwood; many logs are mainly sapwood, which is very susceptible to damage by wood boring insects and fungi.

[12] In much of Africa mortars and pestles are still used for grinding seeds, dried flowers, and leaves—both for daily foods and for medicines.

Other Young branches, stripped of their spines, are used as toothpicks. The hard round seeds are used for rosary beads, necklaces, and playing-pieces for board games (such as *darra* and *warri*). Whole seed is sometimes burnt in a special partial-combustion container to produce a gooey black tar (*ghotran*), employed in treating mange, a skin disease notably affecting camels. In Ahaggar, Algeria, Touareg women have used the oily kernels to lighten their face and suppress black spots on their skin. Balanites is also a common hedgeplant, widely grown, for example, in the town of Tamanrasset, where many inhabitants plant it around their food plots.

NUTRITION

The fruit is bitter when green, but palatable when ripe. It perhaps should not be eaten in excess, as the saponins it contains in various proportions are laxative. Nonetheless, schoolchildren in parts of West Africa reportedly suck 15-20 balanites fruits a day seemingly without ill effect. Given such experiences down through centuries, the presence of toxicity seems unlikely, but uncertainty nevertheless remains.

Nutritional details are variable, but the pulp seems quite nourishing. Its carbohydrate (notably sugars) content ranges from 40 percent (fresh-picked) to 70 percent (fully dry). The dried pulp also contains about 5 percent protein and 0.1 percent fat. Vitamin and mineral contents have yet to be detailed but—as in most dense fruit pulps—are likely to be substantial.

As has been noted, the seed kernels are rich in oil. Amounts from 30 to 60 percent are recorded. This lipid consists largely of linoleic and oleic acids (about 30 percent and 25 percent respectively), and would be classified as unsaturated, the type most desirable in foods. Kernels and seedmeal are also rich in protein (above 25 percent). Apparently, it is only slightly inferior in amino-acid quality to peanut. The seed kernels of most plants generally provide good mineral content, and their oils often contain fat-soluble vitamins. In particular, the golden kernels of balanites probably contain notable levels of carotenoids; groups such as the Dinka who consume them regularly are reported to have low incidents of vitamin-A deficiency.[13]

Although the above analyses indicate a high nutritive value, just how good a food the kernels are remains in doubt. Sometimes they are steeped 3 to 4 days before being eaten, and whether this is necessary, precautionary, or reflective of just certain types is currently unknown. Seedmeal tested on rats showed no gross toxicity.

HORTICULTURE

Whereas the species is basically uncultivated, individual trees have been planted for centuries and in recent times tiny plantations have been

[13] Information from C. Gullick.

Southern Sudan. During all of the years humans have been in Africa, they have been eating balanites' date-sized fruits. Kernels are for supplementary food, famine food, or even the staple food. They are also useful for producing industrial products. (Caroline Gullick)

established in Niger, Chad, and northern Nigeria. From this it is known that balanites is easily established by direct seeding. Seeds are readily available, although they are prone to insect borers which greatly reduce the viability. Those seeds that have passed through goats or camels germinate and sprout readily, and are easily found in places where animals are kept overnight. In a perhaps better way to ensure germination fresh seeds can be placed in water, boiled a few minutes, cooled, and left to soak overnight. An alternative is manual scarification followed by 24 hours of soaking.[14] In addition, wild seedlings can be dug up and transplanted into a plantation setting.

Vegetative propagation is straightforward. As mentioned, root cuttings are used to form hedges. The roots readily form suckers, which are cut off, rooted, and planted. They strike readily. Vegetative reproduction can also be performed using stem cuttings. This ease of cloning makes the species ideal for propagating elite specimens.

The tree grows slowly at first, leaving it vulnerable to grass fires, grazing animals, and weed competition (in fertile soils) for at least 3 years. Once past the establishment phase, however, plants need no protection. They show

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[14] A contributor reports successful direct seeding without supplementary irrigation in a severe region of the northern Sahel, where total rainfall was 172 mm. Seeds were removed from their shells, soaked for 12 hours in 30°C water, and sown at 3 cm depth (twice the diameter) after the rains had properly started. There were 500 to 2,500 seeds per kilogram. Information from Eden Foundation.

excellent persistence and appear immune to almost all natural injuries. Some hedges in the Sahara are believed to have survived at least a century.

Management is not an imperative, but in dry areas pruning helps the trees survive drought. The trees coppice readily, and bounce back without lasting damage even after heavy pruning.

Seedlings mature relatively slowly. The first fruit yields can be expected in 5-8 years, depending on plant and on location. Once fruiting begins, however, the tree can go on producing annually for at least 75 of its 100-year lifespan. And for all those decades it can be extremely productive (an average yield is said to be 125 kg of ripe fruit per tree).

HARVESTING AND HANDLING

The fruits are usually harvested from the ground. Like true dates, they store well in dried form, and are often put aside for use during the hungry season. However, they do not keep as well as dates and those destined for longtime storage must be gathered before they ripen.

Compared to the fruits, the seeds store much better—up to a year if they are clean, dry, and protected from insects. The kernels are subsequently extracted by cracking the seeds open by hand or by boiling them in water until the shell bursts apart. Next, a bitter principle in the kernel must be eliminated. This is usually done by cooking the kernels twice and then either steeping them 3-4 days or leaching them with hot water (60°C) for 2 days. As noted earlier, the debittered kernels are tasty and can be roasted like peanuts, used in sweets, or ground into the paste like peanut butter.

LIMITATIONS

Uncertainties and qualifying factors are to be expected with what is basically an undomesticated species. As to the plant itself, there are problems of slow and erratic growth, irregular fruiting, sharp thorns, frost sensitivity, susceptibility to browsing, and damage by certain insects. As to the seed and fruit, there can be difficulties with insects and rodents unless care is taken. In farm fields the trees may compete with nearby crops for moisture in the root-zone. However, this depends on the local conditions, and on pastureland balanites reportedly makes a good companion crop.

A principal obstacle to the fruit's commercial exploitation has been the difficulty of obtaining adequate and regular supplies.

There are technical difficulties too. One is removing the sticky skin on a large commercial scale. Another is the woody shell that limits industrial utilization of the seed. Although machines for separating this hard covering from the kernel have been described, they all tend to crush the seed. As of yet, no one has invented a machine to extract the kernels whole and undamaged via mechanical means—a major constraint to developing food products from this nut in quantity.

Balanites is not recommended for planting outside its native habitat. After reaching Curaçao in 1885, for example, it infested that dry Caribbean island. Goats favor the fruits and are the major disperser of its seeds.

NEXT STEPS

With a plant of such diversity, dispersion, and usefulness the task of presenting a comprehensive picture of its developmental needs is daunting. Below are a few possibilities.

Making Use of the Existing Resource A 1979 survey found trees in the Sudan yield more than 400,000 tons of fruits per year. The one million trees in Blue Nile Province produce at least an estimated 100,000 tons. Of those, only about 2 percent reached any marketplace in that barren and sparsely populated area where transport and communications are difficult. The rest go to wildlife or rot. In such places more needs to be done to help local people, most of whom live in poverty, take better advantage of the potential in their midst. This is true in countries from Mauritania to India.

Food-Security Activities This reliable, resilient, and beneficial species could be a powerful weapon in projects to make life more secure in locations that too often need food relief due to drought. Tests, trials, and support for balanites plantings and development in places such as the starvation-plagued Ogaden and Konso regions are encouraged. When drought arrives, these may save much hunger, if not many lives.

Stopping Desert Creep Contrary to popular impressions of a few years back, the Sahara is not marching relentlessly on its way to the ocean, but the movement of sand dunes and degradation of land are nonetheless serious problems. Indeed, desertification threatens to demolish roads, tracks, railways, waterways, town, farms, villages, and dams—all of which are being denuded of vegetation, due to drought and overuse, and are being left vulnerable to the irrepressible Sahara sands.

To combat the advance of the sand, officials and laypersons alike have initiated many measures—mechanical, chemical, and biological. Tree planting, however, remains the most popular and practical. Over the entire Sahelian region small farmers are planting trees to keep their land from turning to desert. Eucalyptus and neem are perhaps most popular, but of all the trees tried so far, balanites is among the most effective. It is one of the very few that can survive on dunes in locations where annual rainfall is as low as 100 mm. Moreover, the locals particularly favor it for its wood, fruit, fuel, forage, and its medicinal value.

This tree thus could have a civil benefit of great importance even if its products never become widely exploited. It could end up protecting the vital infrastructures of a dozen countries.

International Cooperation As this crop is as at home in Arabia and India as it is in Africa, there are possibilities for joint and parallel research activities in developing balanites. The value to the Empty Quarter of Yemen and Saudi Arabia and the Thar Desert of India are perhaps as great as to the Sahara sands. Indeed, in India (where the species has long been called *Balanites roxburghii*) the fruits are often much larger than in Africa. Through grafting or cross-pollination the Indian plants offer a possible key to rapidly improving the production of balanites fruits in Africa and the Middle East. Cooperative research, testing, DNA analyses, and much more are well worth fostering.

New Plantings Although existing natural stands are extensive and may be useful for industrial purposes, the greatest commercial hope lies in organized plantings of select, superior material. Indeed, balanites shows such promise as a resource that immediate plantation trials are highly recommended. In areas where it is already known, efforts need not be delayed by extensive quests for the ideal plant to clone. It should be noted that in the wild the species grows as scattered trees and perhaps may not be amenable to plantation-style production, especially in extremely arid locations. However, there is every expectation that it will adapt well.

Horticultural Development There are no detailed studies regarding optimum cultivation methods, hence there is much scope for improving yields. For example, studies into seed viability, optimum planting times, spacing distances, soil fertility and watering could all lead to improvements. There is also little understanding of pollination and fruit set, or knowledge of pests and diseases and their effects on yield. Thus it would be prudent to investigate issues such as vegetative propagation, pruning regimes for maximum fruit set, spacing, water use, and micro-site enrichment. In these and other research activities, local insights could well prove invaluable.

Genetic Selection A species as variable as this holds much scope for improvement by selection. The tree is so widely distributed across Africa and Asia it seems likely that many different ecotypes, if not subspecies, already exist. It is likely that some with large and sweet fruits, fast growth, high yields, small thorns, or perhaps no thorns are just waiting to be discovered by the observant traveler.

Toxicological Testing Despite the fact that it has been eaten for years, more toxicological testing is necessary before balanites can be wholeheartedly recommended as a major food source. It seems likely that the traditional methods for preparing it rely on leaching out the soapy ingredients. While unpleasant to eat, these saponins are not toxic.

Thou Market, southern Sudan. Across the Sahel, women generate income from balanites seeds, which are about half oil and a third protein. After processing at home, they can be turned into many tasty items, including roasted snacks and a spread not unlike peanut butter. They also supply a vegetable oil that is a prized ingredient in foods as well as in local cosmetics. (Caroline Gullick)

Industrial Development The plant's several products with industrial potential need and deserve further development. These include diosgenin, oil, and various fermentation products. The same can be said for its byproducts (such as protein-rich feeds), which may end up becoming vital resources for many of the world's most needy nations.

Cracking the Nuts As noted, the principle obstacle to extensive commercial exploitation has been the lack of suitable machines for removing the sticky pericarp and for decorticating the nuts. A research breakthrough could transform the potential of this species.

Non-food Uses Just how good the various balanites products are as medicinals, pest-control agents, skin treatments, animal feeds, and chewsticks for teeth cleaning have yet to be solidly determined. Tests should be run. These would make interesting research projects because the tree grows where few or no other sources for such products exist.

Public Health In areas beset by schistosomiasis or guinea worm, planting balanites along the edges of irrigation canals, around water holes, and along the banks of rivers could be tested. Fruits are lethal to the infective stages of these serious disease organisms. However, there is uncertainty over the practicality of such uses because a strong emulsion of the fruits can be toxic to fish. Even if this proves unworkable in natural waterways, it may work in wells and troughs and other constructed water supplies. The fruit's ingredients are not toxic to humans or domestic animals.

SPECIES INFORMATION

Botanical Name *Balanites aegyptiaca* (L.) Del.

Family Zygophyllaceae (Balanitaceae)

Synonyms *Balanites roxburghii* Planch. *Agialida barteri*, *Agialida larteri* van Tiegh., *Agialida senegalensis* van Tiegh., *Agialida tombuctensis* van Tiegh., *Balanites ziziphoides* Mildbr. et Schlechter, *Ximenia aegyptiaca* L.

Common Names

Arabic: heglig laloab, lalob (fruit)
Bambara: seguene, zegene, ségé né,
English: desert date (ripe), Egyptian myrobalan (unripe), torchwood, Jericho balsam
Ethiopia: ghossa, dyemo, shifaraoul (Amharic), bedena (G), hangalta (K), maghe, mogha (T)
French: dattier du désert, myrobalan d'Egypte, savonnier
Gourmanché: bangbaalu
Nigeria: aduwa (Hausa)
India: ingudi-vraksha (Sanskrit), hingol (Hindi, Bengali)
Kenya: mnyra, njienjia, mjunju (Swahili), eroronyit (Turkana), olongosw/u, ol-ngoswa (Maasai), mulului (Ka), otho, sadhto (Luo), baddan (Bor), segene (Bama), tunywo (Pok)
Moré: kielege, kielega
Nepal: cheure (Nepalese)
Senegal: sump (Wolof)
Somalia: ader, goot, kiti, kulan, kullen (Somali)

South Africa: umHulu, umgobandlovu (Zulu)
Sri Lanka: ingudi
Sudan: heglig, heglieg (Arabic), laloub (lalobe), korak, tira, kuri (Nuba)
Uganda: ekorete, ecomai (Ts), too, to (Ach), lugba (Bar), thoo (A), logba, lugba (Md), lubwoti (Rl)
Zambia: kasalusalu, mfwankomo, mklete, mkumudwe, msalu, pulupulu (Ny)
Zimbabwe: nyachoko, muvambangoma (C), muongo (To), nulu (H)
Algeria: teboraq, teboragh, tborag (Tamahâq)
Senoufo: sancere logolo
Mauritania: taïchot (Arabic), murtoki (Poular)

Description

Balanites is a shrub or, more usually, a small tree 3 to 6 m, rarely 10 m tall, with a furrowed stem up to 45 cm in diameter. It is long-lived, and may exceed 100 years. Bark is scaly, deeply fissured, and gray or dark brown. The fissures, which run vertically, reveal the yellowish younger bark beneath. Its stems are intricately branched and the canopy more or less spherical. The slender drooping branchlets bear long green spines and gray-green leaves made up of two leaflets. The trees are either evergreen or wholly or partially deciduous. There is also a narrowly branched taproot, which may penetrate several meters to reach the watertable. On inland dunes in Senegal, lateral roots were dug up and found to extend out nearly 30 m.

The flowers are hermaphroditic and self-compatible, though pollination is usually by other flowers on the tree or out-crossing with other plants. Pollinators are primarily bees, ants, and flies, as well as beetles and the wind. The fruit is a plum-like drupe. Green at first, it turns yellow-red as it ripens. The skin is thin, loose, sometimes wrinkled and leathery, becoming parched when ripe. It is easily removed. The inside parts are composed of a soft, edible pulp surrounding a woody stone. The stone constitutes about half the weight of the whole fruit—the skin and sugary pulp together make up a third, and the seed at the center 15 percent.

Distribution

The species is indigenous to woodlands along the Sahara's southern border from the Atlantic to the Red Sea. It is often commonplace on the savannas across that area. Individual trees have been planted extensively in villages far to the south of its natural range. In eastern Africa, it is found as far south as Natal.

It is also found in Southwest and South Asia. As noted, it was introduced to the Caribbean more than a century ago, and on Curaçao has overrun part of the dry eastern end of the island. It is also growing in Puerto Rico and probably other Caribbean islands.

Horticultural Varieties

None reported.

Environmental Requirements

Balanites is typically found in ecosystems from deciduous bushlands to savanna woodland thickets to open desert, where it occurs mostly in and alongside wadis. The trees themselves occur scattered or as pure stands, the latter possibly being due to human intervention. Owing to their value, balanites are often left to live when all else is felled.

Rainfall The species' precipitation range is 100 to 1,400 mm, but the most trees occur where rainfall is between 250 and 800 mm. In the driest areas, they occur only where the roots can reach groundwater.

Altitude The tree is found from 380 m below sea level (in the Jordan Valley) to 1,800 m above sea level in Ethiopia and Algeria.

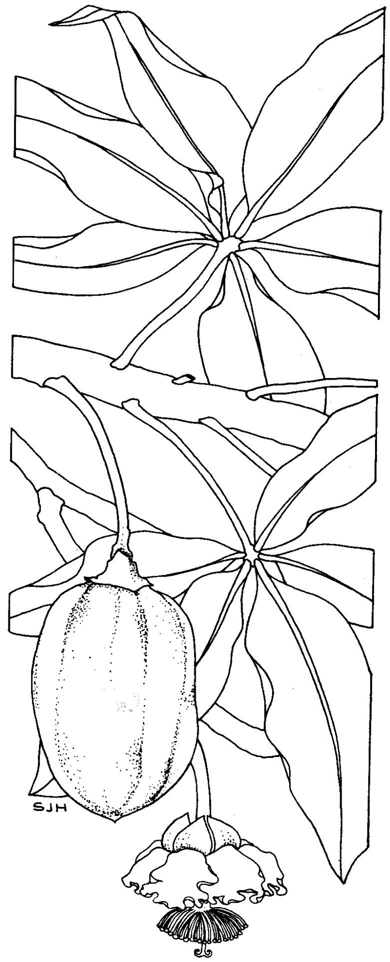
Low Temperature It is frost sensitive.

High Temperature Easily withstands temperatures that soar into the upper 40s day after day.

Soil Balanites trees can be found on a great variety of soils: sands, clay, cracking clay, alluvial soils, and gravel, for instance. However, it clearly prefers clay, and when it is found on pure sand there is usually an underlying layer of clay. Although the plant readily survives periodic inundation, it does not tolerate prolonged waterlogging.

Related Species

Africa contains several other *Balanites* species. Although none seems to offer promise as a fruit crop each is an interesting plant in its own right and is worth some horticultural attention. They typically provide fodder for goats, cattle and sheep, and occasionally camels. But along with the balanites, they could perhaps prove useful in food-security interventions.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BAOBAB

Across much of Africa the baobab (*Adansonia digitata*) is a common sight. Wherever it grows people rely on it for food. Some count this tree's leaves among their most valued vegetables. Others consider its fruits the finer food. And all rely on baobab seed for sustenance during famine times.

This strange tree also provides drink. At the height of the rainy season, villagers commonly prize open a hole in the bark and fill the hollow interior with water (usually from a ditch dug at its base). During the subsequent dry months that tank-in-a-trunk becomes so valuable it is sometimes guarded day and night against parched passersby.[1]

Food and drink are just two of the baobab's blessings. Others include shade, medicines, rope, and various raw materials that make everyday living possible. All in all, it can be said, and with a large measure of truth, that baobab is Africa's Tree of Life.

Probably the most distinctive plant of them all, baobab is unforgettable. The trunk often appears so grotesquely swollen as to suggest a giant brandy bottle. The crooked branches, affixed to the "cork," look like squirming roots shooting skywards. That image is so immediately apparent that baobab is often called the "upside-down tree."

Few plants engender so much respect. Millions believe each tree receives divine power through those "roots" reaching toward heaven. Out of both regard and gratitude people maintain baobab near their houses. Indeed, baobab often seems like some vegetative pet that moves in wherever it finds a friendly family (which in a way it does—sprouting from seeds thrown out in household food wastes). Most baobab trees are individually owned or at least individually claimed for a season[2] and many are passed down the generations like some valuable piece of property. A baobab commonly becomes part of the family, and its death proves as painful as that of a beloved friend.

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[1] On the other hand, in Mali and Burkina Faso it is common to see large clay jugs (*canaries*) carefully placed in the hollow of a baobab tree and kept full of water for the use of thirsty travelers.

[2] Many are claimed by "squatters" who—partly to increase productivity, but mainly to secure their claim to the tree for the coming season—are the first to prune back branches.

Few trees on earth engender respect like baobab. Millions believe it receives divine power through the branches that look like arms stretching toward heaven. The baobab is entrenched in the folklore of much of Africa. This is partly because of its singular appearance but also because of the cures and the foods it provides. (Jerry Wright)

This chapter deals specifically with the tree's fruits, which are as unique as the tree itself.[3] Sometimes reaching the size of melons, they have a furry coating and a tough, gourdlike shell. Cut one across and you expose an arrangement something like an orange, with angular packets of soft pulp surrounding a cluster of seeds.[4] There, however, the similarity stops. Baobab fruit is the very antithesis of an orange: its pulp is dry when fully ripe. Often white, but also yellowish or pinkish in color, this so-called monkey bread is a mealy solid resembling something from a cereal. Indeed, a few hours in the sun easily converts it into a free-flowing flour.

Nutritionally speaking, this strange chalky fruit-powder is like nature's own fortified food. The label on a commercially packaged version now sold across Europe,[5] records that 100 g of it provides protein (5 g), carbohydrate (30 g), energy (130 calories), and fiber. In terms of daily nutritional needs,

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[3] The leaves, which are perhaps the main baobab food Africawide, are dealt with in the companion volume on vegetables.

[4] From this, at least according to one explanation, derives the Arabic name *bu hibab* (fruit with a lot of seeds) and from that in turn comes the English name *baobab*.

[5] Baobab Fruit Company (www.baobabfruitco.com).

that same 100 g of dried baobab fruit pulp also supplies 25 percent of provitamin A, 500 percent vitamin C, 34 percent thiamine (B1), 17 percent riboflavin (B2), and 106 percent vitamin B6. As to mineral requirements, it provides 33 percent of the calcium, 26 percent of the phosphorus, and 50 percent of the iron needed each day.

Considering that this is an unaltered, natural product from the heart of malnourished Africa, those are certainly thought-provoking figures. Moreover its protein has a spectacular amino-acid profile, including surprising quantities of such essential nutritional rarities as lysine (15g per 100g of the protein), methionine (5g), cystine (11g), and tryptophan (1.5g). Is it any wonder, then, that Europeans searching for good health are buying baobab fruit flour?

With a gingerbread flavor enlivened by a high but not unpleasant level of acidity,[6] monkey bread is not for every sweet tooth. However, it is notably refreshing, a feature especially appreciated in the desiccating climates where the tree occurs. Most commonly this soluble powder is stirred into warm water or milk to create a beverage. Each day in West Africa—Senegal, Gambia, and Burkina Faso, for instance—fruits are hauled into cities by the truckload for sale in the central markets and for eventual conversion into this refreshing thirst-quencher. Despite being a sort of poor-person's soda, the drink is important in upscale commerce. One sees it on display, for instance, in supermarkets in countries as far apart as Kenya and Mali.[7]

Proudly displayed there too are baobab sweets. The fruit's pulp is often boiled in sugar and brightened with food coloring to form candies. Children commonly peddle these among themselves; many a budding entrepreneur began her career in commerce selling baobab treats for pocket money.

And sweets and drinks are just two of the fruit's uses. The tart-tasting pulp helps to season the taste of bland foods. West African pastoralists—the Fulanis, for example—use it to acidify a yogurt-like material that is a major food. Known as *nono*, this yogurt/baobab combination is said to relax the nerves after a hard day tending the flock or the field. Millions consider this pick-me-up a necessary part of getting through the afternoons.

Perhaps the fruit's most vital use, however, is to provide food security to those who cannot buy their way out of hunger. For this purpose, the pulp is beaten into thin pancakes, which on exposure to the sun turn into dry disks. Despite a disconcerting appearance, these leathery circlets have an immense importance because they can be stacked up like dinner plates and stored away for months or even years. Poor people in a dozen countries rely on this shelf-stable reserve for sustenance during droughts or other disasters when neither gardens nor markets yield enough. Then, the brown baobab fruit-

[6] This is due to the vitamin C level, which is widely touted as being at least 10-times that of orange.

[7] More commonly, however, the pulp powder is sold rather than the drink itself.

leather is normally boiled up to create a tasty fruity food whose nutritional balance serves to keep the scales of life and death from tipping beyond hope.

And this fruit holds yet more eatables. Embedded in the pulp packets are the clusters of seeds, whose kernels taste like almonds and are rich in both protein and food energy. Although difficult to get at, owing to the seed's thick shell, the kernels are valued foods—consumed fresh, fermented,[8] or roasted like peanuts. In each case the resulting products are typically boiled into a thin gruel with sorghum or pearl millet and drunk like chicken broth or barley water. With their protein, calories, and micronutrients, they add notable nourishment to the daily diet.

Considering that it is perhaps Africa's best-loved tree, baobab is surprisingly neglected by development programs. Until recently, the species was excluded from almost anything dealing with reforestation, agriculture, nutrition, or rural-poverty. Such neglect was not without reason. For one thing, the sight of the bulging trunk and spongy wood makes old-line foresters shudder. For another, the tree is reputedly difficult to grow; the seedlings being both slow to establish and vulnerable to herbivores. And for a third, local people sometimes resist planting baobabs, which they perceive as being "backward" or, worse, possibly attracting bad spirits.[9]

Nonetheless, in many villages young baobab trees are these days often transplanted to a convenient location and then carefully protected from roaming animals. And today the species is finally being included in at least some rural-development programs. Several Sahelian nations are formally producing the seedlings in nurseries and planting them in villages.[10] Although these enterprises are tiny in the context of the overall food needs, most people, including even timber-minded foresters, are at last coming to recognize this tree's potential.

This is clearly a beneficial change in outlook. Nevertheless, the species has far greater promise than is presently recognized. Possibly, there is no better long-term answer more basic or more beneficial to meager rural lives than this ancient food resource. The tree may be tricky to plant, slow to mature, and susceptible to grazing, but once established it becomes nearly

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[8] This is done especially in parts of West Africa, where baobab seeds are often handled like those from locust trees, whose seeds are turned into the famous cheesy fermented solid known as *dawadawa* (see companion volume on vegetables).

[9] Owing to ancient traditions, there are some localized taboos against planting the tree.

[10] Niger in particular seems to have taken up the cause. Several contributors from there have pointed this out. "We have raised, planted and distributed baobab since 1965," wrote one. "In several of our village forestry efforts, people asked for baobab along with the other trees," wrote another. "In Gaya, we have planted baobabs since the early 1970s," wrote a third. Clearly the interest in planting baobab is spreading: "In recent trips through Mali and Burkina Faso, I saw a surprising number of young baobab in small kitchen gardens adjoining family homesteads," wrote yet a fourth.

indestructible.[11] The trunk holds water like a sponge, and it resists drought as well as the dry-season grassfires afflicting the savannas each summer. And a low center of gravity combined with widely spreading roots help mature trees withstand the wrath of storms. Once past its juvenile susceptibilities, a baobab can provide its multifarious benefits for generations to come. The Chinese say that, "it is a wise man whose grandfather planted trees," but to plant a baobab is to touch not just the grandchildren but history itself.

PROSPECTS

Baobab can contribute uniquely to Africans—and especially to the rural poor. Through selecting, propagating, planting, and creating more production as well as through better organizing the mass-markets and processing the fruit on an industrial scale, there is potential for reducing hunger and rural poverty in some of the earth's most difficult-to-feed locations. There is also great promise for establishing "life-insurance plantings" that provide essentially permanent food security for a village, a valley, or a vast region. There is even the possibility of generating worldwide exports in baobab fruit pulp, thereby introducing this ancient food to all mankind. Given concerted action now, the prospects of all these occurring within the next 20 years seem high.[12]

Within Africa

Humid Areas Uncertain prospects. As a rainforest resource, this dryland tree seems hardly promising. However, one report notes that specimens receiving up to 1,250 mm annual rainfall grew almost twice as fast as those planted at the same time in nearby dry areas. Also, notable are the baobabs growing with vigor in humid forests along the Kenyan coast, where rainfall ranges from 1,500 to 2,000 mm.[13] In Mozambique the tree thrives in swamp forests, although there it turns tall and slender, making it appear embarrassingly svelte.

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[11] This longevity is not guaranteed in the presence of elephants, which dote on the fruits and bark and sometimes shred the trunks to access the water inside. This is a problem only in southern and eastern Africa. Elsewhere, there are no elephants.

[12] A monograph on the tree, and its potential, is available online via www.icuc-iwmi.org: Sidibe, M. and J.T. Williams. 2002. *Baobab (*Adansonia digitata *L)*. Fruits for the Future 4. International Centre for Underutilised Crops, Southampton, UK.

[13] These trees produce pinkish colored fruits twice the size of those produced in the hinterland. The leaves are larger, too.

Baobab fruits sometimes attain the size of melons, with their tough shells enclosing angular packets of a strange pulp that is nearly solid. Indeed, a few hours in the sun dries the sticky semisolid into a free-flowing, soluble powder that has a gingerbread flavor as well as a pleasant acid bite. It is nutritious enough to be stirred into warm water or milk to create a health drink. The fruit also contains nuts that taste like almonds. Although difficult to get at (owing to the thick shell) the nuts are valued foodstuffs, eaten fresh, fermented, or roasted like peanuts. They are rich in both food energy and quality protein. (Kazuo Yamasaki)

Dry Areas Excellent prospects. The baobab occurs mainly in savannas. It is not only the biggest tree in the Sahel but arguably the most beloved. Some people have even dubbed it "Mother of the Sahel."

Upland Areas Unknown prospects. The baobab normally occurs below 600 m elevation, but it seems likely that—within the species' outermost temperature- and rainfall tolerances—altitude may be no limit.

Beyond Africa

Although it grows satisfactorily in lands beyond Africa (most famously northern Australia), baobab seems unlikely to become a significant resource in locations where it is now unemployed.

USES

A species like this is certainly hard to categorize in a few sentences. Its more than 30 different products and uses include the following.

Fruits The chalky solid from the gourdlike fruits is consumed in many different ways, however by far the greatest amount is eaten with porridge and/or milk. When employed as part of a hot dish the powdery pulp is often stirred in after the final stage of cooking, thereby preserving the vitamins. In some places, people merely break off a piece of the fruit's outer shell, add water, stir the contents, pour out the resulting solution, and boil it into a tasty and nutritious beverage. The pulp is so acidic it can substitute for baking powder or cream of tartar—in curdling milk, for example. It is also used to make glue for paper.

Seeds The kernels are eaten raw and, as noted earlier, are also fermented and roasted. In each case they are typically boiled with cereal grains to form a thick porridge, thin gruel, or watery drink. During food emergencies these kernels (like the surrounding pulp) become a life-saving staple, both because they store well and because they are exceptionally rich in protein, food energy, and micronutrients.

Flowers Although pollinated by fruit bats, the flowers are also a favorite nectar source for bees.

Leaves Fresh baobab leaves provide an edible vegetable similar to spinach. Today, this is the tree's most important food use. In the companion volume on African vegetables we have devoted a whole chapter to this use.

Trunks By nature, baobab is a trunk-succulent, meaning that its wood typically remains damp. As already noted, people in the drier parts of Africa employ their baobabs as water reservoirs. The trunk may be naturally hollow, but more often the inner tissues are deliberately scooped out. The space within can be huge: As much as 10,000 liters of water has been stored in a single stem. Baobab trunks are also occasionally used for dwellings, storage sheds, bus stops, bars, dairies, toilets, watchtowers, grain stores, shelters, stables, or even tombs.

Roots A red dye can be extracted from the roots.

Environmental Relief Baobabs are sometimes planted for shade, shelter, boundary-markers, or landscaping purposes. In the desiccated center of Mali, where the scenery is unrelieved by any notable permanent feature, they also serve as formal reference points (individual trees are marked, for instance, on the Institut Geographique's National 1:200,000 maps). In the

season when the rains are expected the trees are eagerly watched, because Africa's farmers understand that the greening of the baobab means planting time is at hand.

Fiber In the full-grown tree, the bark is 10-15 cm thick, and the inner portion is composed of tough longitudinal fibers that are so flexible, strong, and durable that even in the era of nylon and steel they are used to make rope, clothing, fishing nets, rugs, mats, baskets, thread, and musical-instrument strings—not to mention paper tough enough for banknotes. The fibers can be woven into coarse fabrics, some of which are waterproof. Senegalese weavers, for example, produce rain hats and even drinking vessels out of them. In addition, the fibers are notable for making supple and extremely strong bags. Many a harvest moves from field to village and then on to market in a baobab bag. Although other tree species die when their bark is stripped off, baobabs not only survive, but quickly regenerate it.

Wood As a timber, the soft and spongy wood quickly succumbs to rot. It is, in fact, spread over fields as mulch. Nonetheless, in Madagascar it is used to thatch roofs.

Fuel The hard bark, the fibrous fruit husks, and the dense shells of the seeds all burn well. Even the corky trunk matter makes an excellent fuel when dried. It is used, for example, for baking large clay pots.

Medicinals Regarding baobab's therapeutic values there are many claims. The bark is widely used for treating chest complaints. Root extracts are applied against skin sores. The leaves are prescribed for stomach and lower-back pain, for kidney and bladder disease, for asthma, insect bites, and more. And the fruit pulp is said to be especially useful for treating diarrhea, something that—given its mineral content and food energy—seems likely to be perfectly valid.

Other Senegalese horticulturists recently learned to bonsai the tree. The miniature, fat-bellied, squirmy-branched baobabs thus created might well prove popular as eye-catching novelties, even worldwide.

NUTRITION

As noted, this fruit is no succulent tropical delight. The raw pulp is about 90 percent dry matter, the exact reverse of expectations in a fruit. That dry matter is nutritionally not unlike that of a cereal or a rootcrop such as potato, comprising: about 80% carbohydrate, 10% fiber, 5% crude protein, and 0.2% fats. In samples from separate trees and locations the food-energy

levels have ranged from 200 to 350 calories per 100 g of dry weight.[14] Given the near absence of fat, this energy must come mostly from carbohydrate, which is said to be rich in pectin and to also include glucose, other sugars, and mucilaginous matter.

As already highlighted, the protein itself has a remarkable nutritional quality. Further, that protein occurs in a surprising amount for a fruit—as much as 5 percent has been measured—and it seems to have a high digestibility in the bargain.

It is the levels of vitamins that distinguish this fruit flour from, say, wheat flour. The fruit pulp, as we have said, is remarkably high in vitamin C content. Individual trees with vitamin C content up to 500 mg per 100g have been found. The "norm," however, is around 200 mg per 100g of pulp (or twice the amount in concentrated orange juice).[15]

The pulp is also rich in several of the B vitamins. Moreover, it apparently contains both free tartaric acid and its potassium salt. Indeed, several minerals have been measured in high levels, including (per 100g) phosphorus (100-200 mg), calcium (300 mg) and iron (7 mg).[16] These are all exceptional figures also.

The seed kernels represent a second, separate source of nutrients. Proximate analyses (dry-weight basis) indicate they can be up to a third crude protein and a third fat, with nearly 10 percent crude fiber.[17] The "baobab nut" thus contains more protein than peanuts and its protein appears rich in lysine, methionine, cysteine, and tryptophan. Moreover, some kernels can contain more oil than soybeans, and that oil provides a fairly good measure of unsaturation; nearly 90 percent of the oil is oleic, palmitic, and linoleic acid in almost equal parts.[18]

HORTICULTURE

Unless pretreated, seeds can take a year to germinate. Commonly, they are dunked in boiling water, usually for less than a minute but sometimes longer. Some, however, are scarified or carefully pierced (to let water in) and then soaked overnight. Sulfuric acid treatments may be most effective.

[14] Respectively, Baobab Fruit Company (baobabfruitco.com), and Saka, J.D.K. and J.D. Msonthi. 1994. Nutritional value of edible fruits of indigenous wild trees in Malawi. *Forest Ecology and Management* 64:245-248.

[15] Information from J. Scheuring.

[16] Saka and Msonthi, 1994, op. cit., and Eromosele, I.C., C.O. Eromosele, and M. Kuzhkuzha. 1991. Evaluation of mineral elements and ascorbic acid contents in fruits of some wild plants. *Plant Foods for Human Nutrition* 41:151-154.

[17] Arnold, T.H., M.J. Well, and A.S. Wehmeyer. 1985. Koisan food plants: taxa with potential for economic exploitation. Pp. 69-86 in Wickens, G.E., J.R. Goodin, and D.V. Field, eds., *Plants for Arid Lands*. Allen and Unwin, London.

[18] Booth F.E.M. and G.E. Wickens. 1988. Non-timber uses of selected arid zone trees and shrubs in Africa. *FAO Conservation Guide 19.* FAO, Rome.

Once treated, most seeds germinate within three weeks.

Horticultural handling methods are essentially unreported, but bare-root seedlings have been transplanted from nurseries with reasonable results. In addition, saplings more than a meter tall have been root-balled and transplanted to the field. The species is hardly known for speedy growth, but on favorable sites its seedlings have reached 2 m in height in 2 years and 12 m in 15 years. This is far above the norm, however, given that few baobabs are planted in favorable sites.

No serious pests or major diseases are known. Young trees are susceptible to both wildfires and browsing by roaming herbivores (wild *and* domestic), but once their middle-age spread begins showing only elephants, lightning, or exceptional cyclones affect them.

Severe pruning is sometimes used to maintain canopy size. Within reason, this does no particular harm, and in fact it probably stimulates greater leaf growth. However, annual pruning naturally does reduce the tree's potential for fruit formation.

HARVESTING AND HANDLING

Villagers often punch foot-holes into the smooth trunk for easy access to the fruits above. Most, though, knock the fruits off from the ground using long poles. The fruits themselves are unusual in that they remain dangling during the dry season long after the tree sheds its leaves. They are also unusual in remaining edible far past the point where other fruits would have decayed into putrefaction. Stored under normal ambient conditions, they keep for up to 3 months, a feature especially important for hungry regions because they are still edible at times when other sustenance is hard to secure. The impervious rind and the dryness of the pulp are probably the major features behind this life-saving resistance to rot.

Typically, however, the pulp is extracted and ground into powder within three months of the harvest. The sifted powder is often marketed in 100g quantities and sold in wrapped plastic bags. The dried pulp powder can be stored for long periods with little loss of vitamin C.[19]

LIMITATIONS

The living baobab is not always a farmer's friend. For one thing, it occupies a lot of room and throws a lot of shade. For another, its spreading shallow roots compete with nearby crops for nutrients and water.[20] And it is an alternative (but relatively insignificant) host of insects that attack cotton.

Although under ideal conditions the plant may be no laggard, slow

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[19] Information from J. Scheuring.

[20] Perhaps for this reason, the areas around a baobab are often patchy or bare of vegetation. However, the bareness may also be due to shade as well as to the inevitable trampling by people and animals enjoying the shade.

growth is the rule rather than the exception. It matures late, too: Trees raised from seedlings take 8-10 years before commencing to fruit and about 30 years before achieving full abundance.

Sadly, many baobabs are now killed by acts of mindless inadvertence. Saplings have slim stems and their own leaf form, so that few people recognize them for what they are. And, going unrecognized, they fall to the common fate of “open access resources”: indifference. Groundfires, goats, gazelles, and galoots stripping off too many leaves destroy the majority of baby baobabs. The absence of protection is a major constraint to the species’ further development.

In some areas cultural values get in the way. Baobabs are subject to many taboos. In the Gambia, for instance, they are considered evil and villagers resist planting them. In addition, many people refuse (purely on principle) to plant any tree that regenerates itself spontaneously.

NEXT STEPS

This single species gets to the heart of so many vital African needs that the time has come to move ahead with vigor. Such a widespread people’s resource is worthy of pan-African cooperation in programs dealing with food, nutrition, agriculture, forestry, agroforestry, horticulture, rural development, home economics, and more.

Baobab is already so useful that background research is not essential to progress. More pressing is the need to employ the knowledge and germplasm already on hand to mount planting, protection, and development programs that combine traditional knowledge with modern scientific understandings. These can be big or little, concentrated or dispersed, rural or suburban. The mass-markets, including those processing the fruit on an industrial scale, also need organizing. Progress may not be quick or easy—given the lack of precedent and the tree’s slow growth—but around baobab plantings whole rural-uplift programs can be built. In that regard, baobab is relevant to operations dealing with:

Rural Poverty In the purely commercial sense, the tree is a prime candidate for developing farm and plantation products for marketing locally, regionally, and around the world.

Hunger Monkey bread, with its balance of protein, energy, vitamins, and minerals, seems capable of improving the food supply (not to mention health) of many societies with little cost or change in daily habits.

Malnutrition Programs focused on nutritional interventions should embrace or at least test baobab as a tool for achieving their goals. The various parts of this plant are not so different in nutritional power from the relief foods shipped in from factories far away. Yet they are locally

acceptable and locally produced. Kwashiorkor, marasmus, avitaminosis, rickets, scurvy, diarrhea, and maybe anemia are among the scourges likely to be relieved by this powdery fruit product.

Food Security This species offers promise for establishing "life-insurance plantings" that provide essentially permanent food security.

Deforestation Tree-planting programs throughout the vast semiarid and subhumid regions of Africa should at least consider planting baobab. The species is a prime candidate for self-motivated forestry and successful plantings will, as we have said, leave a resource for millennia. The tree is not for everyone or every site, but for all that its importance is universal.

Balance of Payments Deficits For a continent short of foreign exchange, it is notable that baobab's export potential could eventually be large. Already, some African nations trade its food products among themselves, something that could be both increased and extended outwards to other parts of the globe. Indeed, an export industry based on the all-natural, soluble powder with potent nutritional punch might be the best economic engine for leveraging the crop to new commercial heights. Employing an African product to improve nutrition in other parts of the world may seem like an irony, but among other things it will induce the production discipline, safety inspections, and quality controls to make baobab better for all Africa too.

Economic Development Beyond fruit products, there are opportunities for successful commerce. To mention a few, there are the tree's use for shade, shelter, water storage, boundary markers, beautification (both in landscapes and cosmetics), and even tourism.[21] In this regard, the bark should not be overlooked. Its fiber may seem esoteric but within Africa it is a *very* important product.[22] And it is a renewable one: Although often completely stripped, baobabs regenerate their bark with remarkable agility.[23] Waterproof baobab hats, bags, and baskets might also well attract worldwide interest and international sales.

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[21] In Madagascar at least certain towns attract visitors from around the world to admire their baobabs. Majunga, for instance, touts its famous baobab, "a more than 700 years old tree [that] makes the city proud." And twenty kilometers north of Morondava there is "the most popular place for baobab spotters, Baobab Alley."

[22] One of our contributors wrote, "this [fiber] is a major use in Mozambique. It is difficult, at least close to villages, to find unscarred trees."

[23] In this regard, it is not unlike Portugal's cork oaks, which produce billions of corks for the world's wine bottles. But their growth and fruit production is also severely stunted.

Wild Resources Although new plantings probably hold the key to eventual success, the existing trees offer opportunities for greater commercial ends. Kenya, to mention just one country, is estimated to utilize less than a tenth of the potential inherent in its existing baobabs. In this vein, the thoughtlessness that now sees millions of saplings mindlessly destroyed needs to be counteracted by educating everyone to protect young baobabs. In a like spirit, the taboos need to be overcome: Baobabs are certainly not evil, and any tree that regenerates itself spontaneously still can use the help of horticulture (especially where fruits are heavily exploited and no seeds ever make it to the ground).

Nutrition Earlier, we presented figures on the protein, mineral and vitamin contents of the fruits and seeds—ones that should be of consuming interest to anyone working to overcome Africa's chronic malnutrition. Such figures, however, have yet to be subjected to adequate independent verification for underpinning continent-wide endeavors. Thus, food chemists should now carefully check the fruit's composition across the plant's range, determining various geographical differences and putting the overall nutritional profile onto a sound footing.

Beyond that, virtually everything relating to nutrition awaits attention: digestibility studies on each ingredient—protein, fiber, calcium, other minerals, vitamins. Studies on how storage and various food-processing methods affect nutrient content also would be helpful.

Clearly, monkey bread could become a key tool for overcoming deficiencies in vitamins, protein, and food energy. Anyone involved with efforts to overcome general malnutrition and its related maladies should consider testing this common fruit food. An important approach to chronic malnutrition might be all around Africa…just unrecognized by the majority.

Food Technology In light of the almost complete lack of basic knowledge of this foodstuff, much remains to be done regarding the science of harvesting, handling, cooking, storing, and processing the fruits and seeds. Food technologists of the world could find much of interest and humanitarian relevance here. Research into variability in flavor and local acceptability might be useful too. In addition, means for detecting fraudulent baobab powder mixtures, which now occur in some markets, are needed.

Although baobab products are widely eaten, it would be prudent to check the fruit-pulp and the seeds for toxic or noxious components that might be detrimental if used more intensively or if fed to malnourished babies. In addition, it would help to have some measure of any hazards due to such things as adulteration, poor sanitation, and bad handling. In this regard, studies on spoilage could be conducted. Despite the fruit's renowned longevity, there is likely to be a place for preservatives as well.

MALI SHOWS THE WAY

In Malian Dogon country, baobabs are often planted in courtyards, carefully grown for 5-6 years, and then carefully transplanted to family owned fields, where the trees are protected from roaming animals.

There are already many examples of baobab “orchards” planted in the periphery of Sahelian towns and cities (Bamako, Mopti, etc). Those orchards are all harvested for leaves rather than fruit—leaves are more abundant and harvesting can commence in a much shorter time than for the case of fruits. In Mali, local agroforestry researches have perfected grafting techniques with close to 100 percent success rate. Already more than 5,000 trees in over 100 farmer orchards have been grafted with stock from trees with extremely high vitamin C content.

In Sahelian Mali and Burkina the fruits are also a major food. Besides domestic consumption, there is an enormous trade of baobab fruit northwards and eastwards in Mali where it is prized alike by Moor, Taureg, and Fula.

Water Why is it that the water inside the trunk of a baobab remains potable for months?[24] At present, there seem no answers that question, and this mysterious process of water preservation needs investigation. Apparently, the living wood leaches natural preservatives that keep water from fouling. Whatever that leachate contains, it must be remarkably good at killing microbes considering that the trees stand firm with sopping trunks for thousands of years.

Edible Oils Despite the fact that the kernels contain only 10-15 percent oil, the tree might make a useful oilseed in spite of its many other uncertainties.. Currently the oil is only rarely used in cooking, but that seems only through a lack of supply. In parts of Senegal (and doubtless elsewhere) people employ it in preparing traditional dishes for certain festivals. It is an attractive golden liquid with a mild taste and good nutritional balance. Exploration by oil chemists is needed.

Horticultural Development Although overall priority should be given to getting more of today’s baobabs planted, parallel programs on breeding and improving the species need to be pursued. Collections of seeds should be made from the different types throughout its distribution range and made available to researchers, non-governmental organizations, and others anxious to advance this species. Here is another opportunity for powerful pan-

[24] That is, as long as the hole in the trunk is covered to block outside contamination.

African cooperation. The differing ways in which separate seedlots perform in different locations across the continent will uncover much about the plant that is currently unimagined, and that information will be of value to all.

Some idea of the yields—of leaves, fruits, pulp, and seeds—and comparisons between top-producing trees is required. This might be a good opportunity for local, national, or regional contests to see who can come up with Africa's "best and fairest" baobabs. Beyond that, comparisons on sweetness, nutritional quality, taste, and other food values could be included. Selecting for seed qualities—including large size, ease of shelling, and high oil and protein contents—could also prove highly successful.[25]

Taken all round, these are important preliminaries for selecting (and perhaps even breeding) baobabs that yield more and better food. The availability of various highly productive forms would transform everyone's view of this crop and facilitate the species' progress toward ultimately becoming a much greater resource.

If there is one breakthrough that would transform the tree's place in world resources it is vegetative propagation. Techniques need to be worked out. Multiplying elite specimens via cuttings or grafts or other method could, all by itself, foster vast new plantings, not to mention new profits and new perceptions. For one thing, seedlings of such clones are likely to produce their first harvest in under half the current time—i.e., at age 4-5 years, like apples and other fruits. For another, it will raise yields, reliability, and overall product quality.

Field management is also an important area for development. Artificial and natural regeneration techniques for managing baobab in the field require documentation and assessment. Age-old experience in the baobab's various locales could be invaluable guides here.

The species' ecological tolerances and preferences are poorly understood. Baobab tolerates many different types of sites, but at least one researcher has noticed "a tremendous response to choice of planting site, even to microsite." This too needs clarifying.

Pharmaceuticals All parts of the tree are used in traditional medicines, but so far there is little proof of efficacy.[26] Pharmacological investigations should be undertaken. Proving or disproving claims will not necessarily be easy: traditional preparation methods are often complex and secret.

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[25] On this point, our contributor John Scheuring reports: "In our work in Mali, we found that people from several kilometers around recognized certain trees for their particular fruit or leaf qualities. In fact the tree with the highest vitamin C content we ever found was already well known locally for its fruit quality."

[26] Much of the early familiarity of Europeans with the baobab came from its fruits, which were commonly sold in the herb and spice markets of Egypt during the 16th century, probably for their medicinal value in reducing or removing fever. The first recorded reference was by the 14th-century Arab traveler Ibn Batuta, who highlighted the trunk's capacity to store water.

The *Pharmacopée Traditionnelle Sénégalaise* recommends the naturally dried pulp of the fruit for use against dysentery, fever, and rickets. Those uses seem likely to be scientifically sound, and rather modest investigations can probably give them pan-African acceptance.

SPECIES INFORMATION

Botanical Name *Adansonia digitata* Linnaeus.

Family Bombacaceae

Common Names

Afrikaans: kremertartboom
Arabic: bu hibab, hahar, tebeldis; fruit: gangoleis
Bambara: sira
Burkina Faso: twege (Moré)
English: baobab, monkey-bread tree, Ethiopian sour gourd, cream of tartar tree, vegetable elephant, abode of the gods
French: tree: baobab; fruit: pain de singe, calabassier, arbre aux calebasses
Fulani: bokki, bokchi, boko
Ghana: odadie (Twi), tua (Nankani)
Hausa: kuka
Jola: buback
Kenya: mbuyu (Swahili); mwamba (Kamba); olmisera (Maasai); muru (Bajun);
Mandinko: sito
Malagasy: Bozo (Sakalava dialect)
Manyika: mubuyu
Ndebele: umkomo
Portugese: imbondeiro
Shona: mayuy, muuyu, tsongoro (seeds)
Sudan: tebeldi, humeira
Swahili: mbuyu
Tsonga: shimuwu
Tswana: mowana
Venda: muvuhuyu
Wolof: bui
Yoruba: luru
Zulu: isimuhu, umshimulu

Description

There is no such thing as a typical baobab—individual specimens vary in size, shape, height, trunk shape, and girth. Nonetheless, no one ever mistakes one. Typically, the tree reaches 20 m with a trunk that is cylindrical, tapering, bottle-shaped or irregular. Although normally 3 to 5 m in diameter, massive trunks can be 10 m across.[27] The lower parts are bare. The top, divides into stiff upward-pointing branches, giving the impression of a bottle full of twigs. The thick, fibrous bark has a smooth, silvery, metallic-gray or purplish surface and a remarkable ability to heal itself when damaged. Surface roots spread far from the base of the tree, although the deep taproot disappears with time.

The biology of the baobab is poorly known. The trees are deciduous, leafing out during the period of maximum heat just before the first rains arrive. Juvenile trees have leaves of simple form, but a mature tree's leaves have segments that radiate outward, somewhat like the fingers of a hand. Trees remain in leaf through the rainy season, during which time they also develop huge pink or white flowers (though flowering can occur at almost any time). These blossoms are solitary and showy, being up to 20 cm in diameter and hanging on long stalks. Their petals are waxy, snow-white, and pendulous. Though they attract abundant bees (and even bush babies), in the main they seem mostly to be pollinated by bats.

The fruits form up to six months after flowering, during the late dry season or early wet season. In shape, they vary from spherical to oblong and slender to ovoid, measuring 12-40 cm in length and 7-17 cm in diameter. Their woody gourdlike shells are up to 1 cm thick and are coated with a velvety coating of yellowish brown hairs. Inside, they contain the powdery pulp, divided longitudinally by fibrous septa into about 10 chambers. Each chamber contains many kidney-shaped, brownish black or purple seeds that are approximately the size of fat beans and have a hard shell. Just how long the seeds remain viable is unknown, but it exceeds five years.

Distribution

The species occurs throughout semiarid continental Africa, from the Senegal coast to northern South Africa. Its northern limit across West Africa is about 16°N; its southern limit is about 15°S in Angola, 22°S in Botswana, and 24°C in Mozambique (at Chokwe). It is particularly plentiful in the Sudano-Sahelian zone and is renowned in Madagascar, where it was introduced probably by Arab traders.

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[27] The earliest Western description of the baobab was by Alvise Cadamosto, who saw some at the mouth of the Senegal River in 1454. He estimated the trunks to be about 11 m in diameter. A naturalist since has reportedly seeing trunks 9.75 m in diameter on trees only 21-24 m high. Those were roughly half as wide as they were tall!

Beyond Africa's shores, baobab has been planted in many tropical locations. Some can be found scattered across tropical America and tropical Asia. Many are found in India, Sri Lanka, and elsewhere around the Indian Ocean owing to Arab traders who carried it there from Africa in the 14th and 15th centuries or earlier. It is also known (together with a local counterpart, known as *boab*) in Australia's "Top End."

Horticultural Varieties

Some varieties have been distinguished, based mainly on fruit shape. But there are doubts as to their genetic validity. In Mali, varieties are indigenously differentiated by their trunk color; white, black, or red.

Environmental Requirements

Baobab occurs almost exclusively in tropical latitudes. It is well adapted to dry and hostile environments and mostly occurs in the semiarid and subhumid zones. A light demander, it does not thrive in dense forest.

Rainfall This species is most common where mean annual rainfall is 200-1,200 mm. However, it is also found in locations with as little as 90 mm or as much as 2,000 mm.

Altitude The tree can be found from sea level to 1,500 m, but most occur below 600 m.

Low Temperature Mean annual temperature: 20-30°C. Frost sensitive.

High Temperature No limits within Africa. In areas where baobabs grow temperatures get well into the high 40°C .

Soil Grows on many different soils but develops best on deep, well drained, generally moist, calcareous sites. Despite being intolerant of waterlogging, it thrives along the banks of rivers such as the Niger. Reportedly tolerates laterite as well as relatively alkaline (e.g., limestone) soils. Apparently does poorly in the sandy "millet" soils of the Sahel.

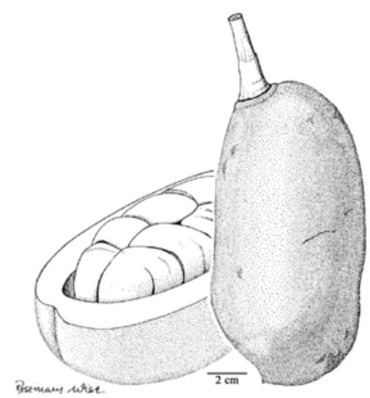
Related Species

The region of origin of *Adansonia digitata* is not clear, but Madagascar is the center of diversity for the genus overall. Of the eight *Adansonia* species, six are found only in Madagascar, one other occurs in Australia, and the last, the baobab of this chapter, appears to have originated somewhere on continental Africa. The six Madagascar species are interesting in their own right. They are widespread on the island's western slopes and are particularly numerous in the southwest. Three are particularly noteworthy for their appearance and utility:

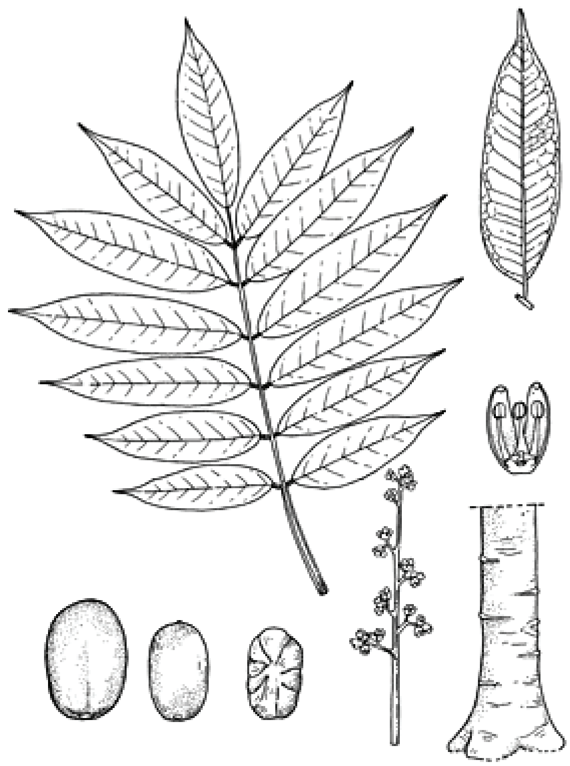
Za (*Adansonia za*) Occurring in the south, west, and northwest, this species—Madagascar's most widespread baobab—forms whole forests, with thousands of ungainly bottle-shaped trees making perhaps the eeriest habitat to be seen anywhere. The seeds are eaten and the trunk is sometimes hollowed out as a cistern. This very big tree reaches 30m in height, with a trunk that is cylindrical, slightly tapering, or swollen. The primary branches, often tapering, ascend properly toward the heavens.

Renala (*Adansonia grandidieri)* The most statuesque baobab of all, this flat-topped species has been called "a pure gem." It has an otherworldly look and is often represented on the cover of books on Madagascar. The fruits are eaten and the seed kernels are so lipid rich they were once exported to France for processing into cooking oil. Nowadays both fruits and seeds are used only locally and on a small scale. Known locally as renala or reniala (Mother of the Forest), it is widely honored as the dwelling place of spirits. Offerings are placed at its base to ensure fertility, fine harvests, and good fortune. Famous groves occur in the western part of Madagascar, near Morombe and Morondava.

Bozy[28] (*Adansonia suarezensis*). This species is restricted to a tiny area near Antsiranana (Diego Suarez) on Madagascar's northern tip. Indeed, its distribution is limited enough to threaten extinction. Given current trends, according to some observers, it is likely to survive only another decade or two. Yet this is a tree with tasty fruits and large edible seeds, which apparently have the highest oil content (46 percent) of any baobab seed. Modest efforts might rescue this species from extinction and also turn it to great benefit. The tree itself is large, up to 25m tall and 2m across. The trunk typically tapers gently from bottom to top and the crown is flat, with branches radiating horizontally.



[28] The name is used for all northern Malagasy baobabs, but primarily this species.



3

BUTTERFRUIT (Safou, Bush Mango)

The colorful prunelike morsels of the butterfruit[1] (*Dacryodes edulis*) are well known in Central and West Africa. They are roasted or boiled with maize as a main course, they are enjoyed (fresh or cooked) as snacks, and they feature in traditional ceremonies and special functions. These are commercial fruits that pour into cities and rural markets in considerable quantities. They are especially important in the hot and humid zone stretching from Eastern Nigeria to Angola. There, women peddling the fruits at locations along the highways are a common sight.

The trees are much appreciated in their own right. They are deliberately planted in and around countless farm plots as well thousands of villages. Indeed, they occur in most or possibly all West and Central African villages. And from the appearance of both the fruits and the trees it is clear that generations of Africans have exercised selection for quality and desirable growth forms. Many of these trees receive at least rudimentary horticultural care. Indeed, good specimens are zealously protected. And when forests are felled and burned to open up farmland, butterfruits are left standing.

As a result of all this interest, the species is a major component of the traditional farming systems in parts of West Africa, especially Nigeria (Eastern, Delta and Edo states), as well as in the four Central African neighbors, Cameroon, Congo-Brazzaville, Congo-Kinshasa, and Gabon. Throughout this region, it is an important source of nutrition and income for many farmers and is among the most widely used fruit trees.

Yet for all its geographical spread, ancient heritage, and current value, butterfruit is barely known to science. This is both strange and sad. People tend to like this fruit once they get to know it. Given a push, it could definitely be a bigger contributor, perhaps eventually reaching millions who today have never heard of it. That would contribute to enhancing the welfare

[1] In popular literature this fruit is often called "African pear" or "bush mango," awkward terms that are botanically and culinarily misleading. A common English name in Central Africa is just "plum," "bush plum," or "African plum," due to its shape and color. It is called safou in Angola, Gabon, Cameroon, and the Congos. It is also known in French as "prunier" and the fruits called "prunes." Because they resemble avocado in composition and texture we suggest "africado" for international marketing purposes.

Butterfruit has not been cultivated to any extent but small organized plantings have already been established in Cameroon. It is, of course, a major component of traditional agroforestry systems, where it is neither scattered nor sporadic. (© Erick C.M. Fernandes, ecf3@cornell.edu)

of farmers in some of the most difficult climates for growing food and cash crops. And it could also enhance survival. In southeastern Nigeria, for example, it is traditionally used to get through the hungry season.[2]

On nutritional grounds alone, the more extensive use of butterfruits could

[2] Information from J.C. Okafor.

be a very good thing. The pulp packs a combination of high protein and high energy that makes it a promising weapon for fighting the world's worst humanitarian problem, protein-calorie malnutrition. Although presently unemployed or even untested in nutrition programs, it could in principle prove a lifesaver for children, nursing mothers, and the desperately sick.

In this regard, the essential amino acid concentrations are noteworthy. The levels of lysine, leucine, and threonine are similar to those found in top-quality animal proteins—eggs, milk, and meat, for example—and much higher than those in most plant staple foods such as wheat, barley, rye, rice, maize, sorghum, or melon seed.

The oil making up one-third to two-thirds of the pulp is also noteworthy. It is a good source of essential fat for human nutrition, being composed mainly of unsaturated fatty acids. Also, it has good potential for such things as salad dressings and cooking oil.

And beyond protein and oil, this fruit provides a good array of minerals, including phosphorus, potassium, calcium, and magnesium. Sodium, on the other hand, is remarkably low (1.5-5.2 mg per 100 g in recent analyses).

Despite its nutritional qualities, the fresh fruit does not appeal to everyone. A dessert delight this is not. Although Central and West Africans may consider it delicious, this fruit turns off sugarcoated taste buds. Indeed, many visitors cannot stand its sourness and slipperiness. One needs to develop a taste for even the sweetest types.[3] This is not as big a limitation as it may seem. This fruit is used mainly as a vegetable, like tomato, and is generally consumed along with maize, cassava, or plantain.

Despite any culinary limitation initial impressions might present, the fruits have enough advantages to warrant much greater development. For one thing, they have a pleasant smell. For another, they are extremely attractive in appearance. Unripe butterfruits are orange, red, pink, or even purple; ripe ones are deep blue, green, violet, or black. On the inside they are just as colorful: the pulp comes in pink, white, green, or pale yellow. The green form is the sweetest; the pink is the prettiest, although most people consider it barely edible.

Although we have chosen to place this plant in the volume on fruits, it could equally well be considered an oilseed. Both pulp and seeds contain outstanding amounts of a vegetable oil useful for such things as cooking and cosmetics. Although this oil is not now produced in any quantity, that could change. The plant comes from the same region as the African oilpalm, which a century ago arose from Central-African obscurity to become one of the world's major crops. According to one estimate, even the nondescript

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[3] One of our contributors wrote: "It has a resinous taste, which one has got to get used to. But then you become an addict!"

These butterfruit are not just transplanted wild types—they differ greatly from wild fruit in the vicinity, which indicates a high degree of selection by farmers. (© Erick C.M. Fernandes, ecf3@cornell.edu)

butterfruit specimens taken straight from the wild can produce more than twice as much oil as their counterparts in the wild oilpalm.[4]

Whereas the tree is grown in myriad farm fields and village compounds, it is not now cultivated in organized plantations. A few pioneering researchers, however, have established experimental plantings in both Nigeria and Congo, and have achieved results that point the way toward larger scale production.[5] Also, oil extraction has advanced to the commercial stage in Gabon and is being tested in Nigeria and Cameroon. And in Congo-Brazzaville, oil processing is being carried out on a pilot scale (100 kg per hour, using an electric oil press).[6]

Beyond commercial production in orchard-like plantings, the tree is an excellent candidate for household plantings. It has particular promise around

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[4] Giacomo, R. 1982. Biologie florale du safoutier (*Dacryodes edulis*) au Gabon. Rapport du projet FAO/CIAM, Libreville, Gabon. Some scientists contend that the butterfruit should have been chosen from the start. It can yield 7-8 tons per hectare, compared with 3 tons per hectare for the wild oilpalm. What it can do in plantations, given some research, is unknown but could be outstanding.

[5] Information from J.C. Okafor. The Congo plants are at the University of Kinshasa.

[6] Riedaker A. and T. Silou. 1998. Safou. Pp. 227-229 in N. El Bassam, ed., *Energy Plant Species*. James & James Publishers, London.

the farm and home because it provides so many useful products—including fruits, browse, wood, and a scented resin that burns with a bright flame. Indeed, it is seen as a reliable friend for both times of need and times of plenty. People like having it nearby.

This versatile species also has promise for agroforestry and utility use. Even now, it is often seen growing scattered in riverbeds, across hillsides, and along the verges of boulevards. It even has potential in plantation forestry. The timber, although small in diameter and short in length, can substitute for mahogany. Its woodworking qualities and interesting appearance suit it to veneers and fine cabinetwork.

Although it has received little formal scientific support, some enthusiasts have rallied to this species. These "crop champions"—who include researchers, extension workers, growers, and traders—joined hands to form a formal bilingual network, the African Safou Network, in the late 1990s.[7] Other groups have also shown interest, and butterfruit is slowly finding a more prominent place in research and development in West and Central Africa.

Three international organizations have also championed the crop. In southeast and southwest Nigeria, the IFAD-ICRAF-IITA Agroforestry project is selecting varieties which better meet the demands of the growing local market. It is also developing propagation and horticultural techniques. Already, the results have caught the attention of farmers, who have long been frustrated by the trees' slow maturity. Butterfruit's potential for greater production and more income appeals to many farmers.[8]

PROSPECTS

Butterfruit could possibly become an African counterpart of the avocado, a protein- and oil-rich fruit that has gone global only within the past 50 years. Avocado is from the American tropics, but is now a substantial resource in a score of countries, including some within Africa itself. Butterfruits are quite unlike avocado in size, shape, or color, but they are very like avocado in their soft, buttery pulp, and in their rich protein and high oil content.

Within Africa

Considering the place this fruit occupies in its native region, there seems every reason to expect that its improved cultivation will be profitable and rewarding there. It also has promise in many parts of Africa that are now unaware of it.

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[7] Information from J. Kengue.

[8] A forward-looking monograph on butterfruit's potential is available in French from the International Centre for Underutilised Crops: Kengue, J. 2002. *Safou (*Dacryodes edulis*)*. Fruits for the Future 3. ICUC, Southampton, UK; see www.icuc-iwmi.org.

Humid Areas Prospects here are high. In much of West and Central Africa's humid-tropical zones, the butterfruit is already well known and the trees are both deliberately planted and protected from destruction when clearing forest. But its true potential as a major commercial crop is not yet tapped. The species is poised for a breakout, but needs the push of better knowledge to get it to the take-off point.

Dry Areas Moderate prospects. The tree withstands extensive dry spells but seems unsuited to truly arid locations.

Upland Areas Uncertain prospects. Although no one knows how butterfruit will perform at elevation, the prospects could be substantial, except of course in those locations where frosts are fierce or frequent.

Beyond Africa

Although so far untried outside Africa, butterfruit is probably not limited to its native continent. Indeed, it seems extremely adaptable and tolerates many combinations of temperature, rainfall, and soils. Taken all round, the species' prospects for both reforestation and nutrition programs seem to be excellent throughout much of the tropics.

USES

This is another of the versatile crops producing multiple products of importance to rural peoples, including the following:

Fresh Fruits The fruits can be eaten raw, but the pulp softens and comes off the seed easiest after a brief heating. For this reason, most fruits are blanched in hot (sometimes salted) water for a few seconds. At times they are softened by a few minutes roasting in the embers of a fire. Some are fried. A newly developed technique is to pack the fruit in a sealed plastic container and stash it in the sun for an hour. This not only softens the pulp and separates the seed, it saves the fuel. Peel and pulp are normally eaten together, scraped from the seed with the teeth as if eating a mango.

Cooked Fruits In some places butterfruits are mostly eaten between meals. More often, the pulp is used to supplement starchy diets based on staples such as maize, cassava, cocoyam, plantain, or sweet potato. In eastern Nigeria the fruits ripen at the same time as maize, and the two are commonly eaten together, usually in the form of snacks.[9] In this case the fruits, as well as the maize, are roasted over the embers of a dying fire. In the

[9] "This is a very delicious combination," wrote one of our contributors in Nigeria. "It sells fast and is expensive."

home this is a minor limitation because it must be cooked after the main part of the meal. For street vendors the problem is more acute because they must keep the fire going, which adds expense.

Animal Feed The species has utility as an animal feed. The leaves are fed to livestock to good effect. The kernel found inside the stone at the center of the fruit contains over 3 percent protein (wet weight basis), and is commonly fed to sheep and goats.

Ornamental Plantings The tree is widely employed for shade. In parts of eastern Nigeria, it is planted in avenues along village roads. Mostly, however, it is planted around gardens and homes.

Wood The heavy heartwood's elastic quality makes it useful for axe-handles, mortars, pestles, and pillars for houses and buildings. It is also suitable for carpentry and fine woodworking. As noted, it is not unlike mahogany, and its woodworking qualities and interesting appearance make it suitable for veneers and for fine cabinetwork.

Other Uses The bark of the living tree yields a resin used to caulk the inner surface of calabashes and to mend earthenware vessels. The waxy gum is also used as a lamp oil and a salve to treat skin parasites. In southeastern Nigeria, the tree is used as an indicator of the planting season: When butterfruit leaves emerge, it is time to plant the crops. The kernel is said to be useful in dissolving stones in the kidneys.

NUTRITION

The fruit's lipid content is extremely high, which is why the tree was initially called "butter tree." Oil constitutes 33 to 65 percent of the pulp, depending on the tree, its maturity, and the care it received. Dietetically speaking, the oil is a desirable one, being made up of 58 percent unsaturated fatty acids (oleic, 34 percent; linoleic, 24 percent) and 43 percent saturated fatty acids (stearic, 6 percent; palmitic, 37 percent).[10] At room temperature (22°C) it separates into a liquid upper layer and semi-solid lower layer, which likely means that the saturated and unsaturated fats are simple to separate. The raw oil has an olive green color, but can be partially bleached to straw yellow. An energy content of 445 calories has been reported.[11]

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[10] Ucciani, E. and F. Busson. 1963. Contribution a l'etude des corps gras de *Pachylobus edulis* Don (Burseraose). *Oleagineux* 18:253-255. For further nutritional information, see also Kengue, op. cit., and Mbofung, C.M.F., T. Silou, and I. Mouragadja. 2002. Chemical Characterisation of Safou (*Dacryodes edulis*) and Evaluation of its Potential as an Ingredient in Nutritious Biscuits. *Forests, Trees and Livelihoods* 12:105-117.

[11] Information from T. Silou.

The fruit is also a rich source of protein. Indeed, crude protein constitutes 20 to 30 percent (dry-weight basis). Its amino-acid composition makes it an excellent supplement to cereals and starchy roots. Lysine and tryptophan—essential amino acids deficient in cereals such as maize—are both present in good quantity in butterfruit. The pulp also contains leucine, valine, isoleucine, tyrosine, arginine, cystine, and threonine, all of which are indispensable to human health and often inadequate in malnourished diets.

Butterfruit has about half the vitamin C of oranges but other vitamin levels seem unreported. Important dietary minerals are present in useful quantities. The contents of potassium (850-1257), calcium (136-210), and magnesium (129-150) are especially notable. In addition, there is iron (2.3-20), copper (1.1-1.7), zinc (1.1-1.5), and manganese (0.56-1.26). Of note, is the near absence of sodium (1.5 to 52mg/100g).[12]

HORTICULTURE

At present, these fruits are mostly gathered from trees cultivated on farms or in village compounds. In other words, there are few intensive plantings. Although production in orchards and harvests from hedges also occur, most of the trees grow singly in gardens.

The plant is traditionally propagated from seeds, which are usually spaced at least 12 to 15 meters apart because of the tree's spreading habit. The stone is placed flat in a shallow hole and covered with a centimeter or two of earth. In Cameroon, the seed is often planted directly at the foot of a banana tree. Although fresh seeds germinate readily, they quickly lose viability. (Clean ones reportedly remain viable 21 days; those with the pulp attached only 7 days.) The seedlings are transplanted when about a year old, at the beginning of the rainy season.

Vegetative propagation has long been considered very difficult. ICRAF researchers at Onne, Nigeria, however, have developed methods for air layering the plant.[13] Budgrafting with juvenile budwood is also possible.[14]

On a farm or in a village, young trees are commonly trimmed to a manageable size for easy harvesting. The species' ability to take heavy pruning is also desirable in agroforestry because farmers can cut it back to reduce the shade cast on crops growing nearby.

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[12] All figures are mg per 100g. Silou T., D. Mampouya, L.W.D. Loka. and M. Saadou. 1999. Composition globale et caractéristiques nutritionnelles des huiles extraites de 5 espèces des cucurbitacées du Niger. *Rivista Italiana della Sostanze Grasse* 76:141–144.

[13] In 2002, ICRAF, with headquarters in Nairobi, changed its name from the International Centre for Research in Agroforestry to the World Agroforestry Centre.

[14] Information from J.C. Okafor.

A difficulty is that these trees come in two "genders": female trees that regularly produce heavy fruit crops and male-hermaphrodite trees that either never produce or produce a small crop irregularly. Unfortunately, only a quarter of the natural population is normally female and three-quarters of the population are therefore useless for food production. Vegetative propagation provides the opportunity to multiply the female trees, especially ones with desirable traits.

HARVESTING AND HANDLING

The fruits are ripe when they have darkened from pink to blue/black. Hand picking typically occurs in the morning, with men or boys climbing into the trees and using hooked poles to draw the fruits within reach. Mature ones are packed into bags (holding up to 10 kg) that are usually hung on a branch. When filled, the bags are lowered on a rope to the ground.

Once picked, the fruits become quite perishable. In the oppressive heat and humidity of tropical lowlands, they do not keep much more than a week. Storage in a cool and airy spot, preferably a basket, helps. Deterioration occurs through moisture loss and the fruit consequently shrivels. Dampness is especially to be avoided; it causes the fruit to soften faster and turn moldy. For this reason, butterfruit is not harvested on rainy days. Similarly, it cannot be packed densely or stored in airtight containers such as plastic bags.

LIMITATIONS

The cropping system, which is mostly traditional and unsupported by scientific verification, seems to have two major constraints: Most stands have too many male trees and the females themselves are too variable—oftentimes every tree bears fruits of different size, character, and quality, making them hard to handle and market.

Farmers report that many trees do not bear regularly. So far, no clear-cut pattern has been detected. The problem may be due to a genetic predilection toward alternate bearing. It may be due to high temperatures (anything above 23°C is thought to reduce fruit set and yield). Or it may be due to pollination failure (perhaps caused by heavy rainfall at flowering time). In addition, it is reported that some trees drop most of their fruits at an early stage of development, which could be due to a nutrient deficiency in the soil.

Currently, the species is strongly seasonal, fruiting during the wet season when other fruits are abundant. Also, the fruiting season is short.

Post-harvest losses can be enormous. In addition to shrinkage and rot, the fruits invisibly lose nutritional value.[15] Part of the problem is caused by bad harvesting technique: resulting in rapid deterioration.

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[15] In one microbiological investigation, such losses were caused by *Botrydiplodia theobromae*, *Rhizopus stolonifer*, *Aspergillus niger*, and *Erwinia* spp. The first two species accounted for most of the damage. Information from J.C. Obiefuna.

NEXT STEPS

This crop seems capable of tackling problems of the poor, of the malnourished, and of the land. It can become a basis for rural development. Obviously, a productive, high-energy, high-protein food like this is worth developing. Now that better growing techniques are known, governments, individuals, and organizations throughout its range should get involved. Steps to achieve better use of the species' potential include the following.

Increased Trade Already butterfruits enter commerce within and between Central and West African countries. But that commerce can be enlarged and made more efficient. Nothing would help this crop's further advancement more. Any increase in "demand pull" will see farmers and traders leaping in to produce and sell more butterfruit.

Malnutrition Trials As noted, the more extensive use of butterfruit in Central and West Africa could be a good thing solely on nutritional grounds. Its combination of high protein, high energy, and good mineral profile makes it a promising weapon for fighting malnutrition. Now is the right moment to test its potential as a lifesaver for children, nursing mothers, and the desperately sick. In particular, the extracted pulp cake might make a useful nutritional supplement. Protein content is lower than common oilseed cakes such as peanut, safflower, and soybeans (ranging from 30-50 percent), but richer than maize, rice, sorghum, and wheat (all 15 percent or less).

Food Security Assessment As noted, people in southeastern Nigeria rely on butterfruit to survive the hungry season. This phenomenon and its replicability elsewhere deserve investigation.

Increased Planting This species is a promising candidate for organized production on an organized scale. Programs to mass produce selected plants and distribute the planting materials to farmers could be especially helpful. In this way, the health and welfare of the people—especially children, the elderly, and the poor—will be improved.

Horticultural Development This highly variable plant is about where the avocado was a century ago: it suffers from a lack of target types upon which to build horticultural production. The discovery of the equivalent of the 'Fuerte' avocado[16] will quickly change the situation. The lack of organized selection or improvement seems largely due to neglect. With more detailed studies, many bottlenecks and difficulties will undoubtedly disappear.

[16] Selected from a California backyard in 1905.

Among horticultural practices needing development are those for:

- Reducing premature fruit drop (abortion);
- Changing the "gender ratio." Whereas a dioecious species like this typically needs only a handful of male plants for every 100 females, plantings in Nigeria have proved to have up to 80 males.
- Improving pollination. The floral biology and the mechanism of fertilization need investigation. This likely will help not only improve fruit-set but the breeding and improvement of the species. Males supposedly produce their pollen poorly and irregularly, but reliable males that shed their pollen at the right time for the local female trees must surely be around;
- Fruiting out of season. Butterfruit would rise in significance if the crop fruited a few months earlier or later. This is not a far-fetched notion. In southeastern Nigeria, for instance, forms that ripen several months after the normal season have been observed;[17]
- Reducing pests and diseases;
- Improving field management. Better practices, alone, will result in better yields and more extensive cultivation.
- Rejuvenating old, but good-quality trees;
- Dwarfing. As with apples, creating smaller plants would make the butterfruit more manageable. Already, it is known that pruning seedling trees to a height of 1-1.5 m produces dwarfing.[18]

Gathering the Diversity This species offers a huge range of genetic diversity. Selection for such things as fruit size, pulp thickness, fruit quality, taste, seed-oil content, tree height, and fruiting season all offer promising possibilities for horticultural progress.

Germplasm collections—both wild and in cultivation—are needed to preserve the range of variation. Special attention should be paid to collecting germplasm in the species' West/Central African region of genetic diversity.

Propagating Select Forms Making selections from the species' diversity is crucial to the crop's future. Vegetative multiplication will lead to plantations of highly productive clones, which would transform this crop almost overnight. The plant has so far resisted many classical vegetative propagation techniques, but much more effort along these lines is warranted.

Fatty Acid Composition Among the many things to select for is polyunsaturation in the oil. The fatty acid composition varies significantly between plants and maybe between countries. Samples gathered in Cameroon, Congo-Brazzaville, Congo-Kinshasa, and Gabon, for example,

[17] Normal types ripen June-August; late types November-January.
[18] Information from J.C. Okafor.

have shown the following ranges: palmitic acid, 41-47 percent; stearic acid 2-3 percent; oleic acid 20-34 percent; and linoleic acid, 19-29 percent.[19]

Diversifying Uses That a food so rich in protein and lipid has not been seriously investigated is surprising. Their functional properties deserve assessment to determine the breadth of possible uses in a wide variety of different industries.

While not showy, the flowers are strongly perfumed and attract masses of pollinators. According to one account,[20] more than 80 percent are honeybees. Thus, butterfruit may well be a valuable honey tree.

Nutritional Research As mentioned, butterfruit seems likely to be very effective for feeding malnourished people. The traditional practice of eating the fruit together with maize, cassava, or plantain should be encouraged. The fruit's low carbohydrate content makes it a good supplement to those carbohydrate rich foods. Because it helps make up deficiencies in minerals and essential amino acids, the fruit neatly balances the starchy staples in the daily diet. It also contributes considerable food energy.

Needed are more measurements on the nutrient content of the many different varieties. Also needing documentation are the ways the fruit is used in traditional diets. Given that information, means for improving and modifying local diets can be determined more precisely.

Food Technology Tropical conditions give a fruit as perishable as this one a short shelf life. Post-harvest storage is one key to its greater commercial use. Refrigeration is an obvious possibility; few technical details have yet been reported, but trials indicate that lower temperature does increase the fruits' storage life. Means for reducing post-harvest losses—including pest- and disease control—would be useful. Pickling and other preservation methods should be tried as well. These could help make the fruit available out-of-season, and especially in the "hungry season" when nutrients such as this fruit provides are hard to find. Nutrient losses using various storage, processing, and preservation techniques also need detailing.

Reforestation Trials The tree has potential for use in environmental-improvement programs confronting such issues as soil erosion, the stabilization of reclaimed gullies, urban beautification, and the provision of shade for parks, paths, roadsides, schoolyards, and bus stops (especially those where children gather). Given the tree's many uses, it can contribute both environmental benefits and food for the needy.

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[19] Information from T. Silou.

[20] Giacomo, R. 1982. Biologie florale du safoutier (*Dacryodes edulis*) au Gabon. Rapport du projet FAO/CIAM, Libreville, Gabon.

SPECIES INFORMATION

Botanical Name *Dacryodes edulis* (G. Don) H.J. Lam

Family Burseraceae

Synonyms *Pachylobus edulis*, *Pachylobus edulis* var. *mubafo*, *Pachylobus saphu*, *Caharium edule*, *Canarium mubafo*, *Canarium saphu*, *Sorindela deliciosa*

Common Names

Bantu: bekwa (Banyangi, a subgroup of Bantu origin)
Benin: orumu
Cameroon: plum (pidgin), sibakwbri (Bakweri), sa (Beti), sa (Ewondo), tsem (Bamiliké), assa, tchou, letse, sau, say (Oroko)
Central African Republic: sene (Tonga), bukoe (Kitembo)
English: African pear, African plum, bush butterfruit, eben tree, native pear, bush mango
French: safoutio, le safoutier (the tree); safout, prunier (the fruit)
Nigeria: iben, ube, oibo (Ibo), elemi (Yoruba), orumu (Edo), eben (Efik), boshu (Boki), orumu, (Urhobo), oromi (Afemai)
Congo: safou, nsafou (Kikongo and Lingala), osaw

Description

The butterfruit tree is commonly 8-12 m high when grown under cultivation in the open, but up to 45 m in the forest and in old plantations. The trunk is generally cylindrical and straight. Although it can reach 1.5 m in diameter, it is normally much smaller. The plant has compound leaves with 4-12 pairs of leaflets (odd-pinnate; with a single terminal leaflet). It is deciduous, losing its leaves in the dry season.

Although the species has male and female flowers on separate plants, there are hermaphrodite (male/female) trees as well. Male flowers are larger (8-25 cm long) than female (5-15 cm long). At least in some vigorous inflorescences, the terminal bud forms the flowering shoot for the following year. Only female flowers produce fruit of course. Although the amounts vary, female inflorescences tend to be very productive. Hermaphrodites are less productive.

The fruit is ellipsoid, globular, or conical; 4-15 cm long, 3-6 cm in diameter. It is rose pink to white when young, deepening to blue, purple or even black at maturity. The pericarp, which represents half the weight of the whole fruits, consists of a thin, waxy, and colored epicarp and a pulpy mesocarp that is light pink, rose, light yellow, light green, or whitish in color. This pulp varies in flavor depending on the tree.

Distribution

Gabon appears to be the center of origin for the genus *Dacryodes*; among the 19 species that occur in Africa, 11 are found there.[21] *Dacryodes edulis* seems to originate in the humid intertropical regions of southern Nigeria, Congo, and Cameroon. As noted, it is cultivated throughout West and Central Africa: the Gulf of Guinea, the interior basin of Congo, Cameroon, Congo, Gabon, Nigeria, Uganda, and central Angola.

Horticultural Varieties

There are no named cultivars but, botanically speaking, the species involves at least two distinct varieties:[22]

- *Dacryodes edulis* var. *edulis* has large fruit, usually more than 5 cm long by 2.5 cm wide;
- *Dacryodes edulis* var. *parvicarpa* has small, more or less conical fruit, usually less the 5 cm long by 2.5 cm wide.

Environmental Requirements

Most of the world's oil-bearing plants are confined to narrow ecological areas. (Oilpalm and coconut, for instance, are restricted to hot and humid areas.) Butterfruit, however, tolerates several. It thrives, for example, in all the ecological zones of Nigeria and Cameroon except the very dry northern provinces. Although it fits well into savanna zones, its fruit production is greatest in the humid forest zones. In general, performance is best in the shade and in good soil.

Rainfall The plant tolerates rainfall from 600 mm to 3,000 mm and more. By some accounts, low humidity at flowering time may frustrate fruiting.

Altitude Low-medium elevation, from sea level to 1,500 m.

Low Temperature Unknown. One contributor reports the minimum at his location as 9°C (in January). Possibly the plant requires "low" night temperature for uniform flowering (22°C or 14°C have been suggested).

High Temperature Thrives where temperatures top 40°C.

[21] Aubreville A. 1962. *Flore du Gabon, No. 3: Irvingiaceae, Simaroubaceae, Burseraceae*. Museum. National d'Histoire Naturelle, Paris.

[22] J.C. Okafor described two varieties, both of which are cultivated (though var. *edulis* is preferred on account of large size). Okafor, J.C. 1983. Horticulturally promising indigenous wild plant species of the Nigerian forest zone. *Acta Hort*. 123:165-176

Soil Seems not to present a limitation. The species has been reported growing on oxisols, ultisols, loamy clay, sandy clay, humic ferralitic soils, deep loam rich in organic matter, andosols, and ferriginous (chalybeate).

Related Species

Currently, 19 *Dacryodes* species are recognized. None of the others has received even the pitiful amount of research accorded the butterfruit. Yet some species produce edible fruits. They, at least, deserve at least preliminary investigation. Examples are:

- *Dacryodes buettneri* (Gabon). Large and important timber tree;
- *Dacryodes igaganga*. Another large and important timber tree;
- *Dacryodes klaineana* (Sierra Leone; common name "damson"). Fruit juicy with a taste said to be "deliciously sweet/sour"; and
- *Dacryodes macrophylla*. Fruit also juicy and "deliciously sweet/sour."

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CARISSA

Carissa (*Carissa macrocarpa*) produces masses of beautifully shiny fruits that look something like plums. Their thin red skin covers a pinkish-red, almost mealy, flesh flecked with a milky juice. Flavor varies from tart to almost sweet, depending upon variety and maturity. In South Africa these are already significant commercial resources. Every January and February in southern Natal, for instance, large quantities are sold, notably along the roadsides.[1] Prized by one and all, they are bought in considerable quantity in cities such as Durban.

Even though production is now haphazard and essentially unsupported by modern horticulture, carissa has good potential as a greater crop. This fruit has an ample edible portion and no stone in the center. It can be eaten whole. Some have a sweet flavor suggestive of raspberry, but most are more like cranberry.

These are versatile foodstuffs. Fresh, they can be eaten out of hand. Halved, they make attractive and tasty additions to salads and desserts. The red pulp looks and tastes so good it is often added to sick-people's foods to entice them into eating bland pasty-colored porridges. The fruits are also dropped into water bottles and gourds to liven up the liquid contents (not necessarily plain water).

Despite widespread use as fresh fruits, carissas are more satisfactory when cooked. They are commonly tossed into soups and stews and squeezed over fish and meat, to which they impart both sweetness and flavor. Many are boiled into brightly colored preserves or fruity-flavored syrups. Some are canned or stewed or baked into pies and tarts.

The boiled juice and pulp have a milky-red appearance but both turn bright red on the addition of a little sugar. Carissa jelly, made by straining or sieving the stewed slightly under-ripe fruits and cooking them with sugar, is considered among the finest in South Africa. It is now gaining aficionados in

[1] In reality, two closely related species occur in South Africa. This chapter focuses on the larger-fruited one, *Carissa macrocarpa*, which is locally called big num-num (grootnoem-noem in Afrikaans). It is indigenous not only to Kwa-Zulu/Natal but also to the Eastern Cape. Outside South Africa, the fruits are commonly called Natal plum, carissa, or carissa plum.

Strictly speaking, the carissa is not an orchard crop—at least not yet. However, it is one of the better-known indigenous horticultural species of South Africa—grown mainly for its hedges, but renowned for its fruits. Not only is a carissa hedge striking to look at and impenetrable, its flowers exude a fragrance as delightful as jasmine, and its shiny red fruits are always in demand. (Forest & Kim Starr, USGS)

California and Florida as well. It has an exquisite color and a delicate flavor. A boiled sauce, whose bite and zing are reminiscent of the cranberry sauce Americans slather over turkey at Thanksgiving, is sometimes prepared; some carissa devotees prefer it.

In spite of their culinary attractions and widespread use, the fruits themselves are not currently produced in intensive culture. Instead, they are obtained from scattered ornamentals and hedgerows, both of which are common across southern Africa. This is because various types of the bush are used for property boundaries, screens, ground covers, landscaping accents, barriers against intruders (two legged and four legged), or container plants. Carissa is also espaliered against a sunny wall or pruned into small trees to beautify a backyard.

Few plants are more decorative, tough, or versatile. The clean and shiny look of the stiff, bottle green leaves makes the shrubs handsome year-round, and the bursts of fragrant flowers and crimson fruits lend added beauty. The star-like flowers, brilliant white against the deep-green foliage, provide special interest during the long flowering season. For this reason, the carissa has become a valued ornamental in California. Hedges of it are to be seen, for example, at the Los Angeles International Airport and at the University of California Santa Barbara.

PROSPECTS

We are far from being the first to suggest that carissa be cultivated on larger and wider scale. So far, however, little along those lines has occurred in practice. Nevertheless, recent decades have seen some progress. In that time, types with large fruit and high yields have been selected, and techniques for their vegetative propagation worked out. Some of these elite plants yield fruits as big as oranges.[2] A few have been selected specifically because they hold their fruits high above the thorny foliage, making them easier to harvest. And in California, some creeping cultivars have been selected for groundcover.

With these (and future) horticultural developments the carissa could become an important fruit of the warmer parts of the world. The species seems poised for greater success, and a handful of horticulturists could set it on its way to culinary usefulness in at least a dozen nations within Africa and without. The benefits of this breakout would go far beyond good nutrition and beautification. The potential for profit may be judged from recent commercial experiences with the cranberry, which in the past few decades has become a billion-dollar resource grown on a mere 10,000 hectares. On its merits, the carissa seems to have a similar potential for producing a terrific return from a tiny area.

This is not to say that the task will be easy. Difficulties include problems with picking the fruits (because of the plant's spines), handling the fruits (sticky milky juice), and preserving the fruits (chilling and handling and dealing with the milky latex juice have yet to be perfected). Nonetheless, relatively modest research seems likely to counteract each of these problems and thereby provide the world a new and especially brilliant crop.

Within Africa

The carissa plant is quite adaptable. It grows especially well in subtropical coastal areas—such as in Natal, southern Florida and Southern California—where it has a competitive advantage over plants that are bothered by sand and sea and ocean spray. But it appears to be adapted to other types of locations, although just how well it will perform as an economic crop is presently far from certain.

[2] Carissas with diameters of 6 cm have been produced in California. Information from C.A. Schroeder.

Humid Areas The promise in Africa's humid lowlands is uncertain and could be slight. The climatic ranges of Africa's various *Carissa* species are currently undetermined, but the plants tend to occur in subtropical and warm-temperate zones.

Dry Areas The species highlighted in this chapter (*Carissa macrocarpa*) enjoys its greatest production (at least given current experience) not in dry regions but in well-watered subtropical and warm-temperate zones. It has, however, quite reasonable, although not exceptional, drought tolerance.[3] On the other hand, a related species, *Carissa haematocarpa*, withstands desiccated sites well, and holds high promise as a dryland crop.

Upland Areas Only trials will tell whether the carissa will prove a useful crop for Africa's highlands. For that particular region, *Carissa bispinosa* would likely be a better choice. Indeed, this relative might become strikingly useful throughout many tropical highlands. In its utilitarian promise it is almost as good as *Carissa macrocarpa*.

Beyond Africa

On the face of it, this is a plant with appeal beyond Africa. It is already cultivated (mainly as a hedged ornamental) in many subtropical areas around the world, as well as in a few tropical locations. But it is possible carissa will become a "cranberry for the warmer regions." Whether (or how soon) this happens will depend more on personal initiative than scientific support or government grant. Although the plant is already sufficiently developed for use as a crop, dedicated individual attention is needed to make it a satisfying commercial success.

USES

Like many species highlighted here, carissa offers many uses, including:

Fresh Fruits In South Africa, most carissas are eaten out of hand. For this, they must be fully ripe, dark red, and slightly soft to the touch. Like a strawberry, they can then be eaten whole, without peeling or seeding (this fruit's most outstanding feature) and have only slight acidity. Halved or quartered, ripe carissas make particularly good toppings for cakes, puddings, and ice cream. They are also much praised in fruit salads, to which they add both sprightly tang and vivid color.

[3] Information from Harry van den Burg.

CARISSA HEDGES

The carissa is particularly valued as a hedge plant. It is used extensively in the southern half of the United States as an ornamental shrub and hedge planting. It withstands shearing admirably and its growth is compact and low.

"To make a hedge," wrote David Fairchild, the dean of US plant explorers, "is a very simple matter. The seeds are sown in a seedbed, and when the young plants are 15 cm high they are transplanted to the place chosen for the hedge and set a foot apart, alternately in parallel rows, distant from one another a foot or more. As the plants grow they are trimmed into the desired hedge form, and the oftener they are trimmed the thicker they interweave their tough, thorny branches, making an impenetrable barrier for stock of all kinds. When in flower the white jasmine-like blossoms show off strikingly against the dark background of foliage; and the red fruit which follows is quite as pretty."

Processed Products This is the carissa's most immediate market. It may be processed into canned or frozen fruit, jelly or preserves, salads, sherbets, and sauces as well as juice. When less than fully ripe, they are very acid. Indeed, they can be considered a sort of "Africanberry," yielding tangy sauces and jellies resembling those North Americans enjoy with turkey. As noted, unripe carissas are also good for jelly and jam, pies, and tarts.[4] They are preserved whole by pricking, cooking briefly in a syrup, and sterilizing in jars. Peeled or unpeeled, they are also made into syrup or sweet pickles. Manufacturers of jams, jellies, and other foodstuffs can add a small proportion of ripe carissas to enhance the red color. Fruity vinegars are produced from overripe carissas. Even carissa wine is a possibility.[5]

Hedges Because of the strong spines, this plant makes great barriers. As has been mentioned, it is particularly valued for this in South Africa. It is especially useful for landscaping and privacy screens near the ocean because it tolerates both salt spray and wind damage. It also makes a sturdy, protective, stock-proof hedge for farms and homes. Even when closely trimmed, it continues yielding fruit in abundance, and home hedges are a major source of the fruits now sold. Prostrate cultivars that hug the soil are widely employed in California as groundcover.

[4] At this point in the draft one of our contributors enthusiastically scrawled: "Good jelly with venison!"

[5] One contributor attests to that fact. "I've tasted some very nice amateur wine from it," he wrote on an early draft.

The pulp is sweet and milky red. It provides an excellent quantity of vitamin C. (Cori Ham)

NUTRITION

The carissa has relatively large quantities of sugar as well as sufficient acid and pectin to make good jelly. It is an excellent source of vitamin C, containing somewhat more than in the average orange.[6] However, it is only a fair source of the other vitamins investigated. The fruit also contains calcium, phosphorus, and magnesium.

HORTICULTURE

This plant is easy to grow. Seeds germinate in 2 to 4 weeks but the seedlings grow very slowly at first. Plants grown from seed may begin producing fruit within 2 years,[7] but they are highly variable and some prove unreliable and sparse bearers.

Vegetative propagation is preferred. Air-layering, ground-layering, or shield-budding are all possible. Cuttings planted directly after removal from

[6] One analysis found 53 mg per 100 g of whole fruit. Wehmeyer, A. S. 1986. *Edible wild plants of southern Africa: data on nutrient contents of over 300 species*. Council for Scientific and Industrial Research, Pretoria.

[7] Contributor Cori Ham notes, “I have a record of a carissa seedling bearing fruit just 18 months after germination.”

the parent bush do not readily form roots unless grown over bottom heat. However, a method has been devised whereby nearly cutting grows.[8] This consists in notching young branchlets by cutting them about halfway through. These are then bent downward and allowed to hang limply. After two months, when a callus has formed over the notch, the cutting is removed from the parent and placed in sand under a lath shade. Within a month it strikes roots. Such cuttings typically begin producing fruit within 2 years.[9]

Maintaining the plants is simple. A standard, balanced fertilizer for fruit production seems to suffice.

Pollination can be a problem. In its homeland, small beetles, hawk moths, and other night-flying insects visit the flowers. Elsewhere, various degrees of unfruitfulness have been attributed to inadequate pollination. Hand pollination is possible. In future, however, all hazards of poor pollination might be avoided by using plants whose floral structure favors a high degree of self-fertilization. Some of those have already been selected.

Even when grown solely as a fruit crop, carissa is often pruned into the form of a narrow hedge. This increases accessibility of the fruit, apparently without diminishing yield.

As a fruiting bush, the plant requires little pruning beyond cutting it back to restrain exuberant growth. If left uncontrolled the bush becomes too “spready” for easy access to the upper section where the fruits form. As long as not grossly overdone, trimming the plants is beneficial in that it induces more fruiting tips to develop. The plant may also be trained as a vine along a trellis, although this creates a straggling form of growth and seems to produce fewer fruits.

HARVESTING AND HANDLING

The main fruit production occurs in summer. The productivity is high, and 3 tons per hectare is considered a minimal yield under commercial production in South Africa. When growing conditions are favorable, the plants produce many off-season fruits as well.

The ripe fruits must be handled with care. They are thin-skinned, easily bruised, and highly perishable. Like peaches, they ripen at slightly different times, so each must be harvested as it ripens.

LIMITATIONS

All parts of the plant exude a milky sap when cut or broken. This is not poisonous but it often can mar the fruit’s appearance. As in figs, however, it

[8] Information from Edward Simmonds.

[9] Cori Ham also noted: “At the University of Stellenbosch, we’ve found that carissa propagates easily from cuttings if we use a commercially available growth hormone called Seradix B number 2. We’ve also found that the cuttings bear fruits after just 6 months in the nursery. They are grown under irrigation and set fruit continuously.

disappears with cooking. Stewing or boiling causes the sap to adhere to the pot (which must not be aluminum) and it can be easily rubbed off with a dry paper towel or a cloth soaked in salad oil.[10]

The fruits have a short shelf life because the "milk" in the red flesh congeals. This is a concern in discerning markets and where the fruit is unknown. For the same reason, the cooked pulp and juice can turn an ugly, milky red. Adding sugar, however, transforms them into a brilliant and beautiful shiny red treat.

The shrub is viciously thorny; to pick the fruit without jabbing yourself is difficult. Moreover, the fruits themselves are often pricked and punctured, which induces decay and blemishes.

Carissas are eaten fresh only when fully ripe. They are best if eaten the day they are picked. Under-ripe fruits lack the tangy, raspberry-like flavor and their latex tends to coat the mouth.

NEXT STEPS

Many things can be done to move the carissa forward into greater use. These include the following:

Varietal improvement There is much variation in carissa. In quality the fruits range from soft and many-seeded to firm and almost seedless. Many advances seem possible through selection and breeding. These include:

- Creating plants with fewer or shorter spines (to facilitate harvesting);
- Developing fruits with longer shelf life;
- Improving the fruits' flavor, appearance, and juiciness; and
- Raising the productiveness of the plants; some fruit very prolifically while others fail to set more than a few fruits (despite blooming freely).

Plantation trials During the testing phase little genetic development is needed: the selections available are already of adequate (although not ultimate) quality. Tests and trial plots using better clones should be established to study the yield-per-hectare, the management methods, harvest requirements, and other features that have to be done on a practical scale.

Horticultural advancement In addition to genetic improvement, yield must also be raised and the regularity of fruiting smoothed out by such things as irrigation, fertilization, pruning, and the inducement of dormancy. In United States, various degrees of unfruitfulness have been attributed to inadequate pollination and the unproductive plants, apparently self-infertile, have been cross-pollination by hand, after which they bear fruits normally.

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[10] At this point on the manuscript, contributor Cori Ham noted: "The milky latex gave problems in manufacturing nectar. The latex settled out in the bottles into an unattractive white layer and it also stuck to the equipment causing a major cleaning operation."

As carissa (i.e., *C. macrocarpa*) grows so well on its own roots, there seems little point in seeking compatible rootstocks. However, Firminger, an English horticulturist who worked in India in the mid-19th century, stated grafting carissa onto seedlings of karanda (a related Asian species, *Carissa carandas*) rootstock considerably increased fruitfulness and reduced the tree's size, making it easier to handle and harvest. This needs reconfirming.

SPECIES INFORMATION

Botanical Name *Carissa macrocarpa* (Eckl.) A. DC

Family Apocynaceae

Synonyms *Carissa grandiflora* (E. Meyer) A. DC; *Arduina macrocarpa* Eckl.; *A. grandiflora* E. Mey.; *Jasminonerium grandiflorum* (E. Mey.) Kuntze.

Common Names

English: carissa, carissa plum, Natal plum,
Ethiopia: agam
French: carissa
South Africa: amatungulu (Zulu)[11], big num-num, grootnoem or grootnoemnoem (Afrikaans), um-tungulu (Xhosa)
Uganda: epwakai/oba, acuga, enyonza, omyonza, omweronde

Description

The carissa is a large shrub or small evergreen tree as much as 6 m tall when left to grow free. It is twiggy, densely branched, and its stems bear long, strong, stiff, bifurcated spines. All parts contain milky latex. The species includes much genetic diversity and types varying greatly in growth habit, cold tolerance, spine shape and form, self-compatibility, and fruit characters have been observed.

Plants from seed usually grow into branchy shrubs, though a few become (after many years) attractive small trees with substantial trunks. Those grown from cuttings vary from prostrate ground covers to tall hedge plants. Cuttings tend to sucker badly unless all belowground buds are first removed.

Fragrant, white flowers—up to about 5 cm in diameter—appear intermittently all year (especially in warm areas near the coast), but most abundantly in spring and summer. They are big, attractive, and reminiscent of star jasmine. Some gardeners compare their sweet fragrance to jasmine; others to orange blossoms.

[11] Amatungulu is a plural; for one fruit the Zulu name is umntungulu.

Some carissa plants bear flowers that are functionally male. These male blossoms are larger than normal, their anthers are larger, and the stamens are much longer than the style. Functionally female flowers have stamens and styles of equal length as well as small anthers that produce no pollen.

The fruits appear in summer through fall, but at least a few can usually be found ripening every month of the year. They are paired berries, ovate to spherical, and 2.5 to 5 cm long. A fully ripe fruit has a waxy skin that is bright crimson streaked with darker red; it is thin and bruises easily. The flesh inside is deep red or crimson with white mottling. In the center are about twelve small brown flat seeds. Some are nearly round while others are elongated and pointed at both ends.

Distribution

The carissa is a common coastal species in South Africa. It is found on sand dunes and on the edges of coastal forest in Eastern Cape Province northwards through Natal to Mozambique. Now widespread tropically, it has become fairly common in southern Florida and is established in cultivation in southern California.

Horticultural Varieties

Horticulturists in South Africa, California, and Florida have selected and named carissa types that tend to bear more reliably than normal.[12] These are now being propagated vegetatively to reproduce them true to form. They tend to have large oval fruits of good texture and few seeds; they mature evenly and have good qualities for making jellies and for pies. They are also very productive.

In California, cultivars selected for fruit quality and productivity include Fancy (an erect form bearing many large fruits with few seeds), Torrey Pines (produces good crops of fruit and abundant pollen), Frank (low yielding, but a good supplier of pollen), Chelsey, and Serena. In Florida one of the best fruit bearers is said to be Gifford.

Efforts have been directed to the development of dwarf, compact, less spiny types for landscape use. Popular among these are: Bonsai, Boxwood Beauty, Dainty Princess, Grandiflora, Green Carpet, Horizontalis, Minima, Ruby Point, Prostrata, and Tuttle.

Environmental Requirements

The plant's climatic limits are basically unknown. However, based on present-day knowledge, it requires a warm, moist subtropical location. It

[12] A list is given by Julia Morton in, Morton, J.F. 1987. *Fruits of Warm Climates*. Julia F. Morton, Miami, Florida.

accepts a variety of exposures including full sun and fairly heavy shade. In shade it tends toward taller growth.

Rainfall Although native to coastal areas with annual rainfall of about 1,000 mm, the plant is drought-resistant and requires no watering in summer rainfall areas. As noted earlier, it has reasonable drought tolerance.

Altitude Unreported, but in Swaziland, it reaches about 1,000 m. A likely upper limit for good growth is 1,500 m.

Low Temperature The carissa grows where temperature rarely falls below freezing. Well-established plants can, however, survive -5°C relatively unscathed. Young plants need protection when the temperature drops to about zero.

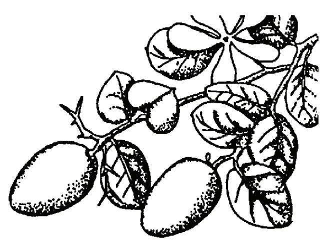
High Temperature The upper limit is unknown but during summer in Pretoria it survives temperatures up to 32°C (in the shade). Best growth is obtained in full sun.

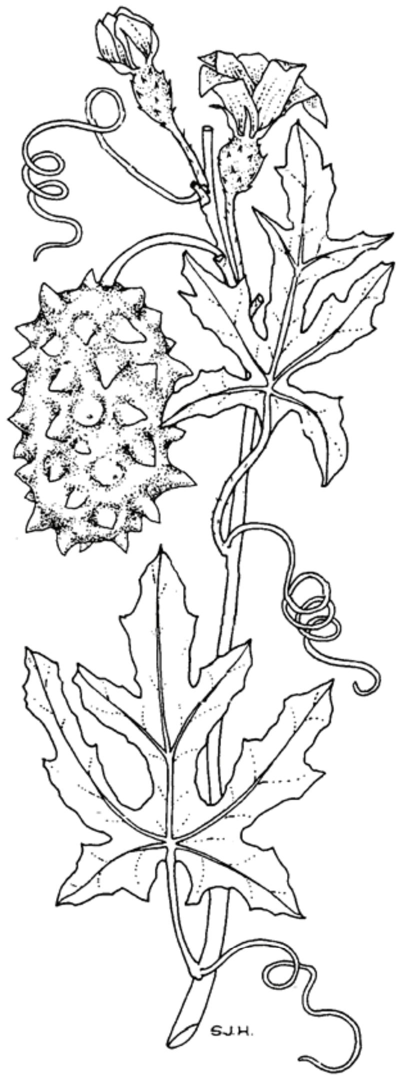
Soil The plants are not exacting in soil requirements. Almost any substrate, limestone heavy clay to sand, is fine as long as it drains well.

Salinity Carissa is quite salt tolerant. For irrigation purposes, water of 8 mmho conductivity (about 5,000 ppm) is acceptable. As mentioned, it withstands salty spray, making it a good choice for coastal gardens.

Related Species

Generally speaking, *Carissa* species in Africa occur in two vast belts from Senegal to Sudan, and from Ethiopia to South Africa. These, too, produce edible fruits. At this stage, they remain undeveloped and the fruits seem less tasty then the species from Natal. As noted, however, *C. haematocarpa* may have special potential in drier areas, and *C. bispinosa* at altitude. A few *Carissa* species are also found in Europe, Asia, and Australia. Though *C. macrocarpa* currently seems most promising as a potential cultivated crop, the others deserve exploratory research and testing.

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HORNED MELON

Horned melon (*Cucumis metulifer*) is one African fruit that has broken into international commerce, albeit recently, and largely on its looks alone. Until you see one, it really is difficult to appreciate its appearance. One author described it as "an extraordinarily attractive object, simultaneously ugly and beautiful." Others use words from "cute" to "horrifying."

The unique appearance of today's horned melon[1] is what sells the fruit in increasing numbers worldwide. It has moved beyond curiosity to become fairly common in many upscale markets, often because people like to eat it but more often for its outstanding (and long-lasting) visual qualities. In fact, from a global perspective, horned melon is as much an ornament as a food.[2]

This surprising success became possible when, in 1982, an adventurous New Zealand couple began cultivating this formerly obscure and essentially wild African fruit. Among its genetic diversity, John and Sharyn Morris found a horned-melon specimen whose fruits were breathtakingly brilliant. They learned how to produce it on a commercial basis. They designed special shipping boxes. And within two years they were exporting their Kiwano® to Japan, where it aroused intense curiosity and sold readily.

Soon fruits were being flown to the United States, and then they began arriving by container loads on ships. In all U.S. history, few fruits have been heralded with more hyperbole. One fruiterer who markets over a hundred specialty crops reported that, "Horned melons created more furor and generated more curiosity than any produce item we have helped introduce to the American scene." Moreover, American farmers started to grow their own. Israel too began commercial production, and now sells fruit to Europe under the name Melano®. It is now also grown along the Mediterranean, and Kenya too is exporting these strange-looking fruits. Most are still shipped by air and, despite the high costs passed on to consumers, they sell.

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[1] Other common names include jelly melon, métulon (France), and the trademarked names Kiwano® (New Zealand) and Melano® (Israel).

[2] Such uses should not be dismissed just because they don't feed the buyer; the desire for ornamental plants around the house can put good money into a growers' pocket. After all, the biggest use for the nearly $200 million pumpkin crop in the United States is the hollow Halloween jack-o-lantern; the flower industry is of course worth billions.

To eat a horned melon, you slurp down the vivid green jelly inside. The embedded seeds are soft and normally swallowed at the same time. The taste? Some liken it to lime, others to cucumber, and yet others to a ripe-banana/green-banana cross, or even pomegranate or papaya. Yet others say that it is just like itself and little else; whatever the taste, it grows on a person. Many cultivars have no hint of cucurbit bitterness, and there are good opportunities for improving the overall flavor. The sugar content in some selections has already been doubled. But the primary allure for buyers is still its appearance, both as a whole-fruit decoration or as a beautiful garnish when sliced or diced.

Of all the world's fruits, perhaps none has a better shelf life. The horned melon is a buyer's dream, sometimes remaining in good condition for 6 months at room temperature even in the tropics. It ships without refrigeration, and in the home, uncut, it can remain a delight for months. Indeed, this is one fruit that must be kept far away from cold. Chilling softens it and makes it susceptible to molds. Cool *decreases* shelf life.[3]

The horned melon can also be a seller's nightmare. Anyone who harvests and packs it must wear gloves because the leaves have needly hairs and the piercing horns on the fruit make it hard to handle. Shippers use nylon brushes to quickly and easily grind down the sharp spikes to rounded nubs, so people can then handle the fruits without stabbing themselves. Even so it is necessary to protect each fruit, for the ground-down projections can still easily spear adjacent fruits unless there is space or a barrier between them.

Despite the fact that this money-maker seems like a modern creation from New Zealand, the crop is actually an old one out of Africa. It grows, usually wild and not abundantly, in the warmer climes of southern Africa, and sporadically as far north as Nigeria and Ethiopia and even eastward across the Red Sea. It is a resilient plant, found especially clambering along roadsides and gully fringes as well as on fallowed and abandoned lands. It seems to prefer life among the weeds, and it is commonly overlooked by passersby. Of course, the average wild specimens are not nearly as colorful or distinctive as today's cultivars, but they are nonetheless unmistakable.

In a few parts of Africa, people cultivate this plant in backyard plots, adding its fruits to their salads and other dishes. A few even garden it commercially. It is well represented, for instance, in Malawi's food markets. Flesh and seeds are eaten raw, and in places the immature fruits are relished like cucumber. Wild fruits are also baked whole like pumpkin, especially across the Kalahari, and are also sun-dried for future use. Nonetheless, in most parts of its native habitat, hardly anyone knows this fruit well.

The horned melon has already revealed to the world one rewarding facet of its character. Although this chapter naturally focuses on its surprising

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[3] Ironically, this has proved to be one of the biggest problems with marketing horned melons in the United States. Supermarket managers are so used to cooling and watering their produce that they cannot break the habit.

A spiky orange oddity crammed with white seeds and vivid green jelly, the horned melon has gone international in recent decades, with several nations shipping it around the world. Back in its African home, the plant is still little used. Seemingly, much more could be made of this strange comestible, one of the few fruits with green flesh when ripe. (© 2005 Monica Palacios-Boyce, Ph.D.)

commercial success, readers should not ignore other merits–such as long storage life or resistance to grazing–as they work to bring this plant to its full potential. Currently, essentially only one genetic aspect of horned melon is exploited: its stunning visual appeal.

Expanding research on this profitable quality will continue to have pay-offs, but visionaries should not let this blind them to other possibilities that are perhaps contained in the untapped biodiversity of this widespread species. Any plant from the same genetic pool as melon and cucumber, yet which has such high tolerance to disease and drought, deserves much greater attention from plant champions. For example, expanding its now-thin flesh could be a goal, perhaps developing a much-needed substitute for disease-bedeviled cucumbers and pickling gherkins. Maybe targeting baking qualities could yield a new, staple-like source of carbohydrates. Even fiercer spines might be emphasized, creating prickly "desert water bottles" that ward off four-legged thieves while holding their moisture for humans. Other innovators might focus on the abundant seed. As with other "lost" fruits, combining imagination, hard work, and a little luck might transform horned melon into an indispensable part of Africa's own fruit repertoire.

PROSPECTS

What future this brilliantly delightful member of the cucumber clan will have is anyone's guess. In its present form, it may prove a fad that collapses. Many people are disappointed who bite into the fruit anticipating a taste to match the exciting appearance. On the other hand, so many people pay good money for its looks that this alone might motivate clever horticulturists to overcome any perceived culinary constraints. In Africa, Zimbabwe, Botswana, and South Africa already grow sweeter selections. A great tasting horned melon might become a major crop to join its cousins, the melon and watermelon (see chapters in this section). Other routes may also open. In particular, its potential as another "cucumber" seems promising.[4]

Within Africa

Humid areas Uncertain. The plant can thrive under humid conditions, but tropical heat and humidity tend to foster vine growth over fruit set.

Dry areas Good prospects, especially when irrigation is available. This is its native habitat and, in Botswana for instance, the plant survives where the rainfall is around 450 mm rainfall. However, it generally needs to be irrigated like melon to get reliable commercial production and to extend the harvest beyond the rainy season.

Upland areas Fair prospects. The plant is found naturally occurring to elevations of about 1,000 m. However, the level of success as a fruit crop depends on temperature; uplands whose growing season is cut short by cold may be problematic.

Beyond Africa

Some types should produce almost anywhere melons thrive (see Chapter 8). In Israel the crop is mainly grown (under irrigation) in the Dead Sea Rift, where heat and other conditions are extreme.

USES

This fruit is generally eaten raw or transformed into juice. Not everyone likes eating horned melon out-of-hand, but those that do usually cut it lengthwise and serve it "on the half shell." Another method used by

[4] Additional prospects, as well as greater technical detail than possible here, are outlined for horned melon and an increasing number of other African species by Plant Resources of Tropical Africa at www.prota.org; see Preface.

harvesters and packers in New Zealand is to cut off one end, loosen the jelly inside with a knife or clippers, put to mouth, and squeeze.

The fruit can also be used in prepared form. There are claims it is, "the best thing ever to happen to a salad"; others believe that it is at its most delicious when simply mixed with plain yoghurt. In France, chefs make sorbets from the pulp. Various "green" drinks have been concocted as well, while pouring the pulp over vanilla ice cream is said to create a special treat, the sweetener in the ice cream bringing out the flavor latent in the fruit.

In Botswana. whole ripe fruit are baked in the coals of fires. They are also peeled, split open, sun-dried on both sides, and stored as ready-made preserves. This cucumber relative can also be used as if it were one. Immature fruits are often peeled and eaten raw, tasting like cucumber. Both these and the small, hard, wild forms are also often pickled like gherkins.

The leaves—like those of other members of the family—are picked when young, boiled, and eaten like spinach. The leaves have a high concentration of useful minerals, but the presence of antinutritional or toxic components is unknown.[5] One contributor notes that they're "not too tasty," a frequent criticism of highly nutritious leafy vegetables.

NUTRITION

The fruits are more nutritious than cucumbers, having notably higher values for most nutrient components. One analysis shows the fruit to be about 90 percent moisture, and containing (on a dry-weight basis) about 10 percent protein, 6 percent fat, and 45 percent carbohydrate, with only about a third to a half the vitamin C of fresh oranges.[6]

By analogy with its relatives, it seems possible the soft flat seeds–which have a nutty flavor–are rich in both protein and oil. If indeed good for you (see Limitations), these might make them an important foodstuff, especially in malnourished regions.

AGRONOMY

Although this fruit is produced commercially in New Zealand, France, Israel, Kenya, California, and elsewhere, few details on how to grow it properly are published. The seeds are reportedly hard to germinate, but one of our contributors wrote, "Seeds germinate readily if they are prepared as

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[5] It was recently reported that mineral concentrations in the leaves exceed 1 percent of plant dry weight, "a much higher value than typical in conventional edible leafy vegetables." Odhava, B., S. Beekrumb, U. Akulaa, and H. Baijnathc. 2007. Preliminary assessment of nutritional value of traditional leafy vegetables in KwaZulu-Natal, South Africa. *Journal of Food Composition and Analysis* 20(5):430-435.

[6] Arnold, T.H., M.J. Wells, and A.S. Wehmeyer. 1984. Khoisan food plants: taxa with potential for future economic exploitation. Pp. 69-86 in Wickens, G.E., J.R. Goodin, and D.V. Field, eds., *Plants for Arid Lands*. George Allen and Unwin, London.

follows: "The seed plus jelly is diluted by water and one should let it stand until it begins to smell and is contaminated with fungi (about 5-7 days at room temperature). Then they must be well washed from all jelly, which contains some inhibitory factor for germination. Next step is to dry the seed in air on nets and keep them dry til use." Some growers report greater production if plants are established in nurseries and then transplanted.

At first sight, the growing plant would seem to have no particularly special requirements. Practices used in cultivating squash, melons, or cucumber are likely to bring success. But we are told that Israeli researchers have found that irrigation regimes, fertilizer applications, sowing dates, and stand densities all affect yield and fruit quality considerably. In particular, it was found that fruits growing on the ground suffer blemishes and off-colors. Premium fruits are therefore grown on high trellises.

This climber grows well under trees or in thick bush and is said to "leap" onto a fence post or a fence wire in full sun. Israeli farmers grow it using open fields, shade houses (open to the air), and greenhouses (closed), a combination that allows them to supply the fruits year round.

The plant is notably resistant to disease and pests, including many of other cucurbits. In the wild its only enemy seems to be a caterpillar that eats its way into fruits lying on the ground. In several experiments with other cucurbits, it proved the one most resistant to nematodes (*Meloidogyne incognita* and *M. javanica*). It is also ignored by the pumpkin fly (*Dacus bivitattus*), a fruit fly that is the bane of curcurbit agriculture in Africa.

Nonetheless, diseases can be a problem. Israel has encountered several viruses (notably, zucchini virus), and perhaps bacteria causing "water spots" on the fruit. Also, especially in a wetter climate, fungi can be problematic.[7]

When grown in greenhouses the crop needs a pollinator, such as bees. Beehives also help when horned melons are grown in the open. Bees, however, are not naturally attracted to the flowers, and visit only when nothing better is around.

HARVESTING AND HANDLING

Fruits reach full size about 40 days after pollination and the main ripening phase (sugar accumulation and color change) is complete about two weeks later. Harvests exceeding 40 tons per hectare have been reported under ideal conditions. During ripening, fruits exhibit no extra output of carbon dioxide or the ripening hormone ethylene, which in part explains their long shelf life. They are sensitive to ethylene, however, and applying it accelerates ripening, softening the peel and turning it orange in a few days.

As already noted, the horned melon is a food-handler's dream—at least as far as shelf life is concerned. Provided a dry atmosphere is maintained, the fruits will keep for at least six months at temperatures between 17° and

[7] "The plants get all the usual things like mildews," wrote contributor Aliza Benzioni.

24°C. Shipments from New Zealand remain at sea over three weeks at temperatures of 20-22°C and normally arrive beautifully orange, their prongs firm, and without the loss of a single fruit. The only problem likely to be encountered under normal marketing conditions is a slight dehydration, which may be prevented with a light coat of wax.

As noted, refrigeration must be avoided. Chilling kills the taste, softens the skin, and allows even the rounded horns to puncture neighboring fruit. In addition, dividers must be used to separate the layers and keep the fruits from spiking each other. New Zealand exporters separate the layers with cardboard and cushion each fruit in wood wool. Israeli growers pick directly into the final shipping boxes.

LIMITATIONS

All the new plantings and international movements of a spiky fruit crammed with seeds have caused some observers concern that the horned-melon trade is exposing the world to a rampant, vigorous vine that will become an irrepressible weed. So far there have been no reports of serious outbreaks, but for at least 60 years the plant has been naturalized in tropical Australia and is said to be a nuisance, and at odd times a curse. In Queensland, for instance, the plant is a sometime pest of sugarcane fields and farms,[8] although it is not regarded as a weed in South Africa or Botswana.[9] It is also considered a nuisance weed at one location in South Carolina (the USDA Vegetable Laboratory near Charleston) but has remained very localized. So far at least, there has been no evidence of calamitous outbreaks. “After years of production we see no problems,” the Morrises reported in New Zealand, a country traumatized by disasters with exotic plants. And Israel has not encountered problems with the crop turning pestiferous.[10] And one of our contributors writes “Not in Europe,” either.

As noted, the fearsome spines are a hazard. Pickers must wear gloves. In New Zealand, warehouse workers also used protection to push the fruits against brushes and blunt the botanic weaponry, although that process has now been automated.[11]

As has been also noted, many people initially find the horned melon unappealing as a foodstuff. The appearance certainly can be disconcerting.

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[8] *Weeds of Queensland* adds, “it is controlled with herbicides and by disposing of the fruit to prevent reseeding.” Kleinschmidt, H.E. and R.W Johnson. 1977. *Weeds of Queensland*. Government Printer, Queensland.

[9] One of our contributors wrote: “I have never seen it become a pest in Africa. It occurs only in small quantities, and most are widely scattered. The fact that it is sought after by goats and other livestock diminishes its chances of reaching pest status. In any case, it is nutritious, people would eat it if it became common. I have yet to see an edible melon turn into a pest—a ridiculous notion to my mind.”

[10] Information from Aliza Benzioni.

[11] Sandpaper and even files are also used in smaller operations and home gardens.

One cynic has written that it "is roundly unloved on first acquaintance, and tepidly liked by only a few." Nonetheless, this exotic orange-spiky edible is continuously gaining adherents, and not everybody dislikes it at first bite. Taste may be improved by selection, mutation, hybridization, or autopolyploidy, and new selections may be already changing this attitude. Reportedly, even Californians are beginning to enjoy it for its flavor.

In selecting wild fruits, it is important they be of the "sweet" type. Some wild plants yield fruits that are bitter, purgative, and emetic. Details of what these off-types contain are incomplete, but the bitterness comes largely from the toxic cucurbitacins and, probably, other compounds common in cucurbits. One contributor to this chapter wrote, "The wild ones in Botswana are seldom, if ever bitter." Yet, another wrote, "When uncultivated types from Queensland were sold in Australia, the market slumped."

At least some of the plants are daylength sensitive. In temperate zones, they set fruit so late in autumn that they cannot mature before winter strikes. This has been noted in Israel, for example, where it was found that the seeds had to be sown in March or April; sowing in May or June was too late.

Although many seeds are unavoidably swallowed while eating the flesh, and they are also reported as edible when eaten alone, their safety needs greater substantiation, especially if the horned melon is to be developed as a melon-seed crop. There are reports that, as in many plants, the sprouting seed produces a toxic substance in its embryo.[12] In addition, seeds are traditionally also ground into a fine flour and taken with water as a vermifuge to expel tapeworms or other parasites.[13] As noted, the flesh can range from bitter to sweet, and the same is probably true of the seed.

NEXT STEPS

Although proponents may see horned melon as an international success story, the crop is barely beyond its formative years and its domestication has hardly commenced. The future could see it trail away almost into economic nothingness, but that seems unlikely. It might also see horned melon transformed into a mature and respectable resource, one that perhaps is very different from the often tasteless, spiky oddity common today. Actions likely to help include the following.

Breeding Better Fruits Currently, some consumers don't like eating horned melons. However, improvements are certainly possible. Breeding programs aimed at improving their taste without losing their looks are having a big impact. Already, it seems likely that far better types than today's are within reach. For example:

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[12] Frohne. D. and J.A. Pfänder. 1984. *A Colour Atlas of Poisonous Plants*. Wolfe Publishing Ltd., London

[13] Chiej, R. 1984. *Macdonald Encyclopedia of Medicinal Plants*. Macdonald, London.

- Seedless forms have been created.[14] These are small but nonetheless promising. They change the fruit from "a bag of seeds" to a glob of green jelly that is unique. Indeed, researchers in both France and Israel are growing the crop in winter under glass to produce seedless (i.e., parthenocarpic) fruit.
- Manipulating ploidy level (as done in watermelon, for instance) could be a means toward both improving flavor and inducing seedlessness.
- Improvement of taste may be achieved by combining genetic material from various sources.[15]
- Spineless forms of the fruit are also known, and it seems probable that these, too, might prove useful. They could be a new foodstuff altogether—less of an oddity but easier to handle and something like a cucumber with a lime jelly interior.

It is also possible to breed in other directions, toward more seed for example. Although the genetic potential is unknown, the disease-resistant and already seedy horned melon could become a premier crop for producing melon seed on a commercial scale. Also needed are better techniques to remove any fibrous seed coating and, as noted, confirming their edibility after processing (they are usually roasted, which detoxifies many seeds).

Also as mentioned, emphasizing traits already useful in the fields of Africa should not be overlooked. These include types for pickling, or that have even longer storage lives, retain water reserves longer when left on the ground unpicked, or perhaps that even have greater spininess so their fruit with its precious liquid is saved for humans and not slurped down by foraging animals. Many believe its brightest future is as a new "cucumber." Finally, its genetic potential as a leafy vegetable should also be explored.

Indigenous Biodiversity It is highly important to create as wide as possible a collection of different genotypes from as much of Africa as possible to broaden the available genetic variability. It would seem logical that where this plant grows wild, explorers will find a wealth of genetic diversity.[16] Remarkable diversity has been noted at the USDA Vegetable Laboratory, where some introductions are daylength sensitive, some show excellent resistance to nematodes, and there are varying degrees of spines on

[14] Information from J.-Y. Peron.

[15] "We found some lines with higher sugar and others with higher acidity, and crossed each of them with the commercial line," wrote contributor Elaine Solowey. "From that, we got F1 lines with better taste and aroma."

[16] C.A. Schroeder wrote us, "There are, for example, many fine forms in Malawi." However, another contributor reported that the *useful* diversity in Africa was limited. "Generally the variation in the species is surprisingly small. We scanned big areas to find some plants with different appearance and none was what we were after."

fruit from very large to none. It is important that variants be located, and useful types sorted, classified, and evaluated. Getting a better handle on the species' diversity will lay the groundwork for all the developments to follow, and today much needs to be done to outline these genetic features.

Horticultural Development Research to perfect cultivation practices is much needed. Some of this has already begun. In several countries research groups have been intensively studying the crop both under glass and in the open field. Production research needs include the artificial induction of fruit setting as well as optimizing growing conditions. Israeli researchers report getting reasonable yields of quality fruits with brackish irrigation (3.5-4.5 Ds/m), and many believe the salty water enhances the flavor.

The plant's interactions with nematodes, a curse of cucurbits, are certainly worth exploring. Its resistance could prove an important general finding, perhaps even giving this species a role in crop rotations—cleansing the soil of these very destructive soil nematodes. One group of researchers has also shown that using horned melon as rootstock for melon in root-knot infested soils can reduce galling, shoot-weight loss, and nematode levels at harvest.[17] Techniques such as grafting can be important not just in high-value commercial horticulture, but also in the worst of situations where subsistence growers, for instance, have no choice what soils they use for planting their crops.

Helping Other Melons By comparison with its better-known relatives, cucumber and melon, this crop shows exceptional resistance to diseases and pests. Thus, the possibility exists that horned melon could help broaden the gene pool of either or both. All three belong to the same genus, *Cucumis*. Genetically speaking, horned melon is closer to melon than cucumber, but so far no one has successfully crossed any of them.[18] In attempts to transfer pest resistance to cucumber, researchers have found that fruits develop in crosses using horned melon pollen; however, no viable seeds from this chimera have yet been found to carry on these genes.[19]

Although gene transfer is undoubtedly difficult, all avenues seem worth pursuing because success would likely reduce costs for producing both crops and benefit the environment as well. In particular, it might dramatically boost the common melon's resistance to nematodes, whitefly, and major diseases such as powdery mildew, downy mildew, and mosaic virus.

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[17] Sigüenza, C., M. Schochow, T. Turini, and A. Ploeg. 2005. Use of *Cucumis metuliferus* as a rootstock for melon to manage *Meloidogyne incognita*. *Journal of Nematology* 37(3):276–280.

[18] Information from J.-Y. Peron and P. Nugent, who report that the pollen tube begins to germinate but does not reach the ovules.

[19] Walters, S.A. and T.C. Wehner. 2002. Incompatibility in diploid and tetraploid crosses of *Cucumis sativus* and *Cucumis metuliferus*. *Euphytica* 128(3):371-374.

SPECIES INFORMATION

Botanical Name *Cucumis metulifer* E. Mey. ex Naudin

Family Cucurbitaceae

Synonyms *Cucumis metulifer* Naudin[20]

Common Names

Afrikaans: rooikomkommer, rooi-agurkie, wilde-komkommer
Bantu: nku, mutete, mugaika, mukaka, uhufafa
Botswana: magabala, mogau
English: spiny cucumber, horned cucumber, jelly melon, Kiwano©
French: métulon, concombre africain
German: Horn-Gurke, Hommelone
Israel: Melano©
Malawi: cucumber, bitter wild cucumber
Shona: mutete, mugaika, mushonga, mugaka
South Africa: bitter wild cucumber
Tswana: magabala
Venda: mukake
Zambia: mugagachiga
Zimbabwe: mushonga, mugaka, mutete, mugaika (S); ihalabujana; muGumudza'mbga (N)
Zulu: uhufafa

Description

The plant is a sprawling, climbing, or trailing herbaceous annual that scrambles over bushes and trees in the wild. It has slender, hairy stems several meters long. The leaves are long-stalked and heart-shaped, shallowly 3 to 5 lobed, and dark green. Slender, curling, unbranched tendrils arise from the axils. The flowers are small, yellow, funnel-shaped, and opening to 5 lobes. The unisexual male and female flowers grow on the same plant. Seed can be true-to-type unless there is outcrossing. The female flower grows above a prickly green ovary, which enlarges to form the fruit. Honeybees are inefficient pollinators but its natural insect pollinators are unknown.

The fruit is ellipsoid, about 6 x 12 cm, light green at first and ripening to bright orange. The skin usually has a broken pattern of light, scribbly reticulations, punctuated with pyramidal spines topped with a bristle. The "flesh" is translucent, green, and filled with whitish seeds.

[20] This binomial, from 1859, is still the most-often cited scientific name (and should for now be used in internet searches). It has been "corrected" to the proper Latin termination under Article 32.7 of the Vienna 2006 International Code of Botanical Nomenclature.

Distribution

Although the botanical literature claims that this species can be found south of a line extending from Nigeria to Sudan and Ethiopia (and across to Yemen), the primary diversity is far south of that. The main concentrations are in Botswana, Zimbabwe (in mopane woodland), Malawi, Zambia, Mozambique, Namibia, Swaziland, and South Africa (lowveld and extending south along the coast to just touch the eastern edge of Cape Province). Commercial lines are exported from Kenya.

Beyond Africa, the plant is currently under small-scale commercial cultivation at least in New Zealand, the United States, Israel, the Netherlands, Italy, Spain, Portugal, and France. It has also been introduced many other places.

Environmental Requirements

As a general rule, suitable sites for horned melon are those where cantaloupes can be cultivated (see Chapter 8, Melon).

Daylength Flowering and fructification can be influenced by daylength. Flowering induction seems to require short days; days longer than 14 hours halt flowering. On the other hand, short days can lead to parthenocarpic fruits, in which the fruits grew directly from the ovule (like pineapples and bananas) without the intervention of pollination. Details are currently uncertain but the optimum length is said to be 12-hour days.

Rainfall The plant is not particularly demanding of water and performs well with as little as 350 to 550 mm. However, dry air during the harvest period is a benefit.

Altitude Although current commercial experience suggests that the plant performs best near sea level, it is probably better to say that it grows well at low to medium altitudes, up to perhaps 1,000 m. Near the equator, however, the upper limit may be closer to 1,800 m.

Low Temperature The lower survival temperature is probably 0°C. However, cool temperatures during the growing period can suppress growth. A report from France notes that optimum germination temperatures were found to lie between 20 and 30°C. Germination was delayed at 12°C and totally inhibited at 8°C.

High Temperature The plant's growth is largely unaffected by temperatures as high as 40°C; however, it seems that temperatures over about 30°C affects flowering. In addition, germination is greatly inhibited at temperatures above 35°C.

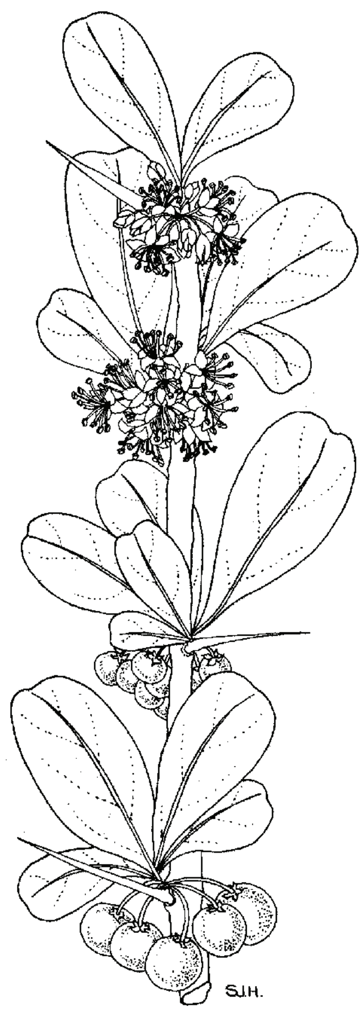
Soil This is a rugged plant in most soil types, and likely to survive in most African locations. However, top yields of quality fruits requires well-drained soils with organic matter and balanced nutrients.

Related Species

The genus *Cucumis* contains around 30 species of the Old World tropics, mostly Africa. It includes both cucumber (*C. sativus*) and melon (*C. melo*; see Chapter 8 in this section). Although cucurbits are notorious for hybridizing among themselves, attempts over the past 40 years to cross these species with horned melon have almost always been uniformly unsuccessful (see Next Steps, above).

West Indian Burr Gherkin (*Cucumis anguria* L.)[21] The burr gherkin has long been used for making fine pickles and is called by some the "true" gherkin (the word traditionally applies to immature cucumbers). Although native to Africa, this small fruit is commonly called "West Indian" gherkin because its cultivation and use is so widespread in those islands. It is also grown, and has also naturalized and sometimes spread as a pest, in other parts of the tropics. In Africa, wild types grow down from Tanzania and across to Namibia, and the cultivated West-Indian forms have been introduced in many places. The small fruits (about 5 cm long) are covered with burrs like horned melon, except the spines are fleshy. Though usually bitter, nonbitter types have been selected in several countries and, in addition to pickling, are eaten fresh, dried, and in soups. The leaves are also eaten. Both cultivars of the West Indian gherkin and the wild types of Africa have drawn the attention of scientists because of potential disease and pest resistance (especially whitefly), but little has been done to explore and improve the horticultural potential of these productive fruits. It is possible that its yield potential is higher than for pickling cucumbers.[22]

[21] Also once called *Cucumis longipes*.
[22] Information from Plant Resources for Tropical Africa, at www.prota.org.



Dovyalis caffra

6

KEI APPLE

Kei apple (*Dovyalis caffra*) is indigenous to the southern regions of Africa, including Malawi, Zimbabwe, Mozambique, and South Africa. Its fruits look something like small golden apples. Produced in abundance, inside their thin, tough skins is a yellow, melting, juicy pulp with a fruity aroma. Although a cultivated crop, horticulturally speaking this plant is poorly developed, and the fruits are basically underexploited. Partly this is because the plants are very thorny. Partly it is because many people don't like the fruit's smell. And partly it is because the pulp can be **very** sour.

Kei apples are sour for the simple reason they have more vitamin C than oranges. Because of their tartness, they are most commonly converted into jams or other preserves soaked with sugar. However, sweeter types that are pleasant to eat raw are becoming available, and this alone seems likely to open new horizons for the crop.[1]

A tall and vigorous shrub with rich green foliage, kei apple[2] is sometimes cultivated in orchards, but mostly grown in hedgerows and as solitary dooryard plants. It is commonly seen in hedges, forming countless rural corrals in southern and eastern Africa. In some climates the untrained plant takes on a rather scraggly appearance, but still makes an excellent hedge. Being evergreen, it provides a year-round screen, while its long sharp thorns deter both people and animals. For this reason, in the 1800s it was introduced, and is still planted, in northwestern Australia, St. Helena, littoral France, Algeria, and Italy, as well as Costa Rica, California, and elsewhere.

This tough shrub does well in almost any soil, including limestone, but cannot tolerate damp sites or high watertables. It is extremely drought resistant and also tolerates salinity, even ocean spray. For this reason, it is especially valued near the sea. It is used as a windbreak and ornamental in coastal California, for example.

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[1] Even these selected types do not appeal to everyone. One of our contributors wrote: "I have had sweet forms of this fruit; they tasted like cold oatmeal."

[2] The word is pronounced "kye," and refers to the river in eastern South Africa that forms one border (and the name) of Transkei. There, this fruit is known as "umkokolo."

The shrubby, thorny, kei apple plant produces fruits that resemble little golden apples. Indigenous to the southern zone of Africa it produces fruits in abundance. (Cori Ham)

Though unexacting in its requirements for survival, the plant produces fruit best in subtropical climates and on humus-rich soils. There, it can become laden with its little golden "apples," in some locations bearing them almost continuously year-round.

In the past, the sourness of even the ripest fruits seemed a barrier to the crop's wider acceptance. But even the sourest kinds could now have a future. In today's markets, fruits need not be sweet to be successful. Cranberry, for example, is bitingly sour and is increasingly used in the United States just for that reason. It gives "zest" (and color) to drinks, candies, jelly desserts, and many other food products.

The sweet kei apples now coming available add a new dimension. For instance, one southern California nurseryman, D. Silber, has selected a type with what he says are large, sweet fruits. He has named it "Arcadian zulufruit" and propagates it by rooting softwood cuttings. Since the plant is so productive, he claims that a single male/female pair can fill a household's fruit needs throughout its fruiting season, which at least in southern California is most of the year.

This is perhaps a glimpse of the potential inherent in this species, but the key for opening the door to the kei apple's future is genetic selection (as is the case for most fruits). However, much more still remains to be done

before the true extent of this species' promise can be glimpsed, let alone fulfilled. The fierce spines are helpful in a hedge but a hindrance in an orchard. Over the years less spiny strains have been selected, but undoubtedly awaiting discovery and development, especially in Africa itself, are even less spiny ones.

PROSPECTS

All in all, a start has been made. However, this plant needs much more research attention before it can contribute significantly to commerce. Needed are better tasting types that are easier to produce as crops. Until then, its major role will be limited to areas where the environment will not permit better-known fruits to be grown.

Within Africa

As of now, the kei apple in Africa is generally restricted to subtropical areas of South Africa.

Humid Areas Prospects uncertain.[3] In South Africa the plant seems to thrive best where annual rainfall is 1,000-1,700 mm. However, there are good hedges of it almost everywhere in the Republic, even in the winter-rainfall Cape region.

Dry Areas Prospects fair to good. The plant seems to prefer dry warm summers, but it has grown well at the Desert Botanical Garden in Arizona, where most of the year is exceedingly dry and exceedingly hot.

Upland Areas Prospects good where the climate stays warm enough. Although the tree itself survives frost, the fruit crop can be lost when a late-winter freeze nips the flowers or flower buds. In the highveld of Gauteng (about 1,500 m elevation), black frosts can go further and wither the branchlets and cause the leaves to fall.

Beyond Africa

As above noted, the kei apple has grown well in several warm parts of the world beyond Africa. There, however, it has not yet generated much enthusiasm as a food resource. In Israel, for instance, it was once extensively cultivated as a hedge around citrus groves, but people did not like the fruits, which accumulated on the ground and became hosts for the Mediterranean fruitfly, a much-despised pest. Therefore, nearly all the plants were destroyed. Such experiences, however, do not necessarily indicate the potential of the selected kei apple strains of today or the future.

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[3] Some contributors said the species would do okay; others said prospects were poor.

USES

The kei apple is not an apple of course, it is a soft, apricotlike fruit with a character all its own. However, it does have similar uses.

Fresh Fruit At present, most people peel the fruit, cut it in half, scoop out the seeds, sprinkle on sugar, and allow it to stand for a few hours before serving it in desserts or fruit salads. In Africa, many people (the Pedi of South Africa, for instance) add kei-apple juice to boiled grains (usually pearl millet, sorghum, or maize) to make a colorful, tasty, and nutritious porridge. This is the fruit's greatest humanitarian potential, and is especially useful in areas where market-quality fruits can't be grown.

Many people do not like the fresh fruit at first; however, a fully ripened sample usually finds good acceptance. Unripe fruits—even "sweet" types—are so exceedingly acid they can be served as "instant pickles." Indeed, in South Africa the young "pickles without vinegar" are served in this manner.

Creative cooks also use the fresh fruits in glacés, drinks, and pastries.

Processed Fruit Because of their abundance and acidity, kei apples are often prepared as preserves. They make amber-colored jellies, jams, compotes, and marmalades. The pulp is high in pectin, so only small amounts are needed to jell other fruit juices, including the most recalcitrant.

A few minutes' cooking turns kei-apple halves into a sauce that adds a fruity tang to meat, fish, or other foods. Simmered briefly in syrup the fruit produces tasty fillings for pies, cakes, or puddings. The cooked slurry can also be diluted with water and sweetened to make very refreshing drink. It is also dried into fruit leather.

Slight heating helps separate the pulp from the seed. Typically, the fruits are covered with water, heated gently (far short of cooking), and pushed through a coarse sieve to remove skins and seeds.

The Living Plant This plant's use as a security hedge has been mentioned. Landowners often intertwine the shoots of young kei apple plants to form interlocking, living latticeworks that are impenetrable. These make excellent barriers against trespassers, four-legged and two-legged, and were formerly relied on around homes in South Africa's sheep and cattle country to ward off wild predators. It is still used for this purpose in the Kenya highlands, where it is one of the most common fencing shrubs.

Other Uses The plant provides good cattle fodder, made more valuable in harsh locations by the plant's resistance to extreme heat- and drought. Because of the spines, livestock leave the foliage untouched until the desperate times arrive. This "bankable" fodder feature is invaluable. In Transkei, for example, kei-apple stock enclosures become critical for saving animals from starvation in the depths of the dry season.

Inside the thin, tough skin of a kei apple is found a yellow, melting, juicy pulp with a lively aroma. The pulp is highly acidic for the simple reason that it contains more vitamin C than an orange. (Cori Ham)

The plant makes a good support for epiphytes. In Natal, the professional and amateur growers of gorgeous orchids (such as *Mystacidium capense* and *M. venosum*) favor it as their "host."

NUTRITION

The fresh ripe fruits are rich in vitamin C (80-120 mg and more per 100 g), as well as potassium (more than 600 mg).[4] Sugars generally exceed 15 percent, with pectin levels nearly 4 percent. Although the protein content is low, generally below 1 percent, the balance of essential amino acids is reported good.[5] Beyond that, little of this fruit's food value is yet known.

HORTICULTURE

To produce fruit on a commercial scale, the trees either are laid out orchard style or are double-set in hedgerows. They can also be espaliered, training the branches onto horizontal supports. With this technique, kei apples can be grown along walls. It works well.

For fruit to form both male and female plants must be present. One properly placed male is sufficient to pollinate at least 10 females.

Kei apple can be propagated from seed, but this is not recommended for purposes of fruit production for several reasons: The resulting plants can

[4] Wehmeyer, A. S. 1986. *Edible wild plants of southern Africa: data on nutrient contents of over 300 species*. Council for Scientific and Industrial Research, Pretoria.

[5] Abdel Fattah, A.F., D.A. Zaki, and M. Edrees. 1975. Some investigations on the pectin and amino acid composition of *Dovyalis caffra* W[arb]. fruit. *Qualitas Plantarum* 24(3/4):311-316.

take 5 years to flower. There is a gross excess of males. The fruit size, shape, and sweetness can differ widely between the plants. And the thorns tend to be of evil prominence.

Vegetative propagation gets around all of these difficulties. The plant can be propagated from semisoft cuttings, air-layers, or budding. Such techniques assure the plant's sex, fruit quality, and relative thorniness. Also, vegetative propagation yields fruits about 2 years earlier than seedlings because the planting materials enjoy an adult's flowering hormones and don't have to endure prolonged adolescence.

Grafting kei apples presents no difficulties. Branches from selected plants can be grafted onto nondescript plants. Male branches can even be grafted onto female rootstock. Indeed, there is graft compatibility with an entirely different genus, *Flacourtia* (best known for Madagascar plum or governor's plum, *F. ramontchi*).

Kei apples bear consistently year to year. For optimum fruit production they need heavy pruning, no easy task with such a spiky species. For one thing, the crown needs frequent thinning because the branches tend to crowd toward the center, ending up in congested tangles of unproductive shoots. For another, the plants become cluttered at the base, making it hard to gather fallen fruits (horticulturists recommend removing all branches up to about 1 m from the ground). For a third, as many spines as possible should be pruned off to ease the harvesting and reduce the likelihood of injury to both pickers and fruits.

Plants grown orchard style should be set about 3 m apart. Males need to be placed so prevailing winds blow the pollen onto the female plants.

HARVESTING AND HANDLING

Kei apples can be hand harvested when bright yellow and tinged with green shadowing. At this stage they are quite tart but will ripen if held at room temperature for about two weeks. As it ripens, the bright yellow skin deepens to gold and the flesh turns almost translucent. The ripe fruit's sugar content has been estimated at averaging 15-18 percent, but even the ripest has some tartness lingering near the seeds in the center. This is not necessarily bad. Indeed, many enjoy the kei apple specifically because of this tang in the center.

Fruit left on the tree will ripen to the firm, all-yellow stage, and then drop. Although classified as a soft fruit, it is remarkably bruise resistant. Small surface blemishes can be avoided by covering the ground beneath the bushes with straw or other soft material. Deeper wounds can be avoided by reducing the spines along the lower branches.

An unusual quality is that once the kei apple is ripe, it resists decay. It then becomes easy to handle and has a long shelf life. However, damaged fruits soften and rot quickly, especially in a rainy, hot, and humid climate.

LIMITATIONS

The kei apple obviously has inherent promise. It has not been more fully realized because of sourness and thorniness. Many people just do not like it. In countries such as Kenya, which know the hedges well, the fruits are all but unused. In Israel (as noted) the plant grew outstandingly, but the fruits were enjoyed only by fruit flies, and this led to its rapid demise at the hands of outraged orchardists. In Florida, too, it has been far from a rousing success.[6] Despite its productivity and hardiness and the promotion of less-spiny, less rampant plants, few Floridians have welcomed it, and its position has remained static for almost a half century.[7]

The juice stains fingers and fabrics a light yellow. Although not permanent, this can be a nuisance.

This does not seem to be a good crop for agroforestry. The plant exhibits allelopathy, its roots excreting chemicals that discourage the growth of other plants in its vicinity. In addition, its roots are shallow and spreading and compete with crops for soil moisture. It is said, however, that deep-rooted crops are unaffected, so perhaps there is a place for kei apple plants in mature tree plantings.

NEXT STEPS

This crop deserves research and development support. It is very important to the lives of some of the world's poorest people. The "zing" that the fruit gives to porridges and gruels cannot be overemphasized. In addition, the nutritional contribution can be important. Nonetheless, much needs to be done before the true potential of this crop can be properly judged and fully availed of. Pressing needs toward that end include the following.

Superior Planting Materials Kei apple awaits a dedicated selection program, particularly to find specimens that bear fruits with less acid and better flavor. Selections can be made from already-selected germplasm of course, as well as from large seedling population derived from selected trees in the wild. Plants producing fruits more appealing to the palate can then be propagated asexually.

A less thorny strain would also be important for both the fruit farmer and the nursery industry. "Many of my customers are turned away by the thorns," reports a contributor. In addition, selections for stress and disease resistance should be sought.

[6] The plant explorer David Fairchild brought large amounts of seed from the botanic garden in Durban, South Africa, to his home near Miami in 1903. For decades rare-fruit growers showed great interest in it, but this has since dwindled. An old plant is still at his home (The Kampong), but few people eat it, preferring instead the hybrid between its relatives *D. abyssinica* and *D. hebecarpa* (ketembilla).

[7] Information from the late Julia Morton. Most were grafted on *D. hebecarpa*.

Despite (or perhaps because of) its sourness, kei apple can give a bite as well as color to drinks, candies, jelly desserts, and many other food products. (Cori Ham)

If true breeding is needed to create elite plants, it could be profitably be directed at combining high fruit quality with thornlessness, productivity, and stress and disease resistance. In this regard, it would be instructive to know more about the inheritance of thornlessness and the inheritance of low acidity/high sugar content in the fruits.

A related, perhaps less urgent, line of improvement would be selection to upgrade the hedges. These might involve upright plant habit, various degrees of thorniness, sterility (so no fruits form), and ornamental value.

Perfect-flowered plants are known to exist. These very rare specimens have *both* male and female flowers on the same plant. In commerce these self-fertile specimens may have particular value because they remove the complexity of obtaining, placing, and planting males for pollination. These dual-gender plants should be sought out, studied, and developed.

Combining this species with others in its genus holds the potential for creating hybrid fruits of high market and culinary appeal. This challenging area offers more than merely interesting possibilities. Innovative amateur and professional horticulturists could find highly satisfying endeavors awaiting them here (see p. 111).

Market Development A crop at this stage of development will not sell itself. For success, various individual efforts are needed. Likely, there are instructive experiences already in its native range. The most promising entry-level market is processed kei-apple products…pastries, preserves, things like that. One California contributor wrote, "Tina, my wife, and I are now doing this is in a small way. Results are surprisingly good. Tina's jam is a hit; 80 percent of first-time tasters like it. I've also sold fresh fruit to Japan and received requests for increased supply."

Horticulture With this crop virtually all horticultural features require investigation. Among pressing needs are:

- *Growing-System Research*. Various avenues to maximize production need to be evaluated. Research should focus on such things as watering, fertilizing, pest control, pruning methods, and measures such as trellising.
- *Harvesting Methods*. Possibly something could be devised for shaking the fruit off, perhaps into a cloth screen laid below the bushes.
- *Security Hedges*. This plant's effectiveness as a security hedge is important to document. Theft is a major problem in orchards. Will kei-apple hedges keep really dedicated thieves out of cherimoyas, mamey, or mango patches? Avocado growers in southern California are desperate for a cheap way to protect their investments. If this species works, there will be a lot of interest. Although hedges are normally grown from seed or seedlings, it is noteworthy that planting hedges of male trees would avoid problems with unwanted fruit littering the area.

Food Technology With this fruit, food technologists could have a field day. Everything needs to be determined from the basic to the most sublime.

Post-harvest handling studies are a particular need. Issues to document include the point at which to harvest the fruits, the ideal storage conditions, and the best packaging methods.

The pectin deserves some study, also. It might well prove to have commercial potential.

The use of kei apple for souring foods should be explored. In recent tests in South Africa, juice from some fruits had a pH as low as 2.5.[8]

The general processing of the fruits offers many special challenges.[9]

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[8] Information from Cori Ham.

[9] "We have tested kei apple for cold storage and the results were very discouraging," wrote contributor Cori Ham, of Matieland, South Africa. "Kei apple blended with guava makes a very nice fruit roll (leather), but consumer tests suggested that pure kei apple is only acceptable as a jam."

SPECIES INFORMATION

Botanical Name *Dovyalis caffra* (Hook.f. & Harvey) Warb.

Family Flacourtiaceae

Synonyms *Dovyalis caffra* Warb., *Aberia caffra* Harv. & Sond., *Aberia edulis* T. Anders.

Common Names

Afrikaans: kei apple, keiappel, wilde-appelkoos, appelkoosdoring
English: kei apple, Dingaan's or wild apricot
South Africa: umkokolo, kei apple, kei appel, Dingaan's apple
Zimbabwe: munhungura, musvisvirondo, mutsvoritsvoto (Shona); umqokolo (Ndebele)
Zulu: umkokolo, iQokolo (fruit), umQokolo (tree), umbambane
Other: motlhono (Sotho); muwhamba, ngundo (Vanda)

Description

Kei apple is a shrub or small tree that grows 3-5 m tall. The trunk and branches are a silvery gray and the leaves are borne on knobby twigs in clusters of two to five. The trees are deciduous but seem evergreen because the old leaves persist until the young ones appear. There are many sharp thorns about 5 cm long, occurring more often on untrimmed shoots than on the older branches.

Cross-pollination of flowers is necessary, as staminate and pistillate flowers are produced on separate plants. Both types lack petals and are inconspicuous. As noted, occasional perfect-flowered specimens exist.

Kei apples are spherical or slightly flattened (oblate) fruits. The diameter is typically 2.5-5 cm. They contain 5 to 15 pointed seeds. When ripe, they are golden yellow, velvety skinned, and crowned with a short stalk and short styles that persist from the female flower. The flesh is juicy and fragrant, with a scent that can become quite pronounced and even repugnant when the fruits get overripe.

Distribution

This native of southeastern Africa is abundant in the wild around the eastern Cape, Ciskei, Transkei, and Natal. It is cultivated in Gauteng (the Transvaal highveld). Mostly, however, it is planted in dooryard collections. It is rare in Zimbabwe, though sometimes cultivated there. In Mozambique, Malawi, Kenya, and Zambia it has been introduced and is cultivated to a small extent.

As noted earlier, it has been introduced into Florida, California, Australia, and the Mediterranean basin. It reportedly has been introduced to Iran and probably other nations as well.

Horticultural Varieties

There are few established superior cultivars, but many good ones could be quickly developed by selecting from wild or seedling populations.

Environmental Requirements

Rainfall Currently, the plant mainly grows where annual precipitation is 1,000-1,700 mm. However, it withstands dry conditions. In the wild, it is found mostly in areas of summer rainfall, where the mean annual precipitation is under 700 mm.

Altitude Usually this species is found in low-lying subtropical areas, from near sea level to about 1,200 m. However, in Kenya it is found up to 2,450 m.

Low Temperature This shrub grows best where the mean temperatures (especially daytime temperatures) are high. However, it is fairly hardy and tolerates brief exposure to cold. In Central Florida, for example, it has withstood -5°C undamaged.

High Temperature The plant's tolerance to high temperatures is seemingly unlimited.

Soil Apparently it grows well on most soil types. However, before investing in large plantings the matter should be investigated because the limits have not been clearly identified. The crop certainly needs good drainage and may perform poorly in heavy clays.

Related Species

In this chapter, we have concentrated on only one species, *Dovyalis caffra*. However, it belongs to a genus with other candidates for fruit crops. Interested amateur and commercial horticulturists could do a lot with this group, which is at present virgin horticultural territory. Various *Dovyalis* species offer possibilities for creating new crops or even hybrids. There is a wealth of germplasm in the genus; Africa, alone, contains at least 13 edible species of *Dovyalis*. All are shrubs or small trees with hairy or smooth fruits. Examples follow.

***D. abyssinica* (African gooseberry, koshum)** This fruit looks, tastes, and smells something like apricot. It comes from a bushy shrub that is common in forests of East Africa (Ethiopia, Somalia, Uganda, Kenya, Tanzania, Zambia, and Malawi). In Ethiopia the plant is commonly used as a hedge. The fruits provide a welcome income for young Ethiopian boys who sell bowlfuls to travelers on the main highways. The fruits are rich in vitamin C, and eaten both fresh and in jams, jellies, and desserts.

The plant occurs naturally in upland rainforest and humid lower highlands (at 1,000-3,000 m in Ethiopia, and between 2,000-2,700 m in Kenya). It is frequently seen along river courses and in dry evergreen forests; sometimes in open wooded grassland. It is said to grow on most soils, provided they are well drained. For purposes of planting, ripe fruits are cracked and allowed to decay for a week before the seeds are removed. There are about 20 seeds per fruit. Ideally, they should be sown immediately in nursery beds, since they germinate readily when fresh but lose viability within a few months.

It has been said that this species "produces fruit superior in quality to those of the closely related kei apple and kitembilla [South Asia's *Dovyalis hebecarpa*] for eating out of hand, and when it becomes better known it will probably become more popular than either of these."

***D. hispidula* (bristly dovyalis)** Not much has been reported about this or the other wild relatives, so the information is skimpy. This one bears spherical fruits up to 2 cm diameter. They are bright red when mature with harsh bristly hairs. The flesh is sweet tasting.

D. longispinus Bright orange to red fruits.

D. lucida This tree reaches 7 m in height. Its fruit is a glossy orange red. Its flavor is reportedly "sourish but not bitter or acidic." It is said to be good for jam.

***D. macrocalyx* (shaggy-fruited dovyalis)** This species is a tree that grows on the forest margins. The fruits hide within an enlarged husk, which is hairy. They are bright red in color, and make excellent preserves.

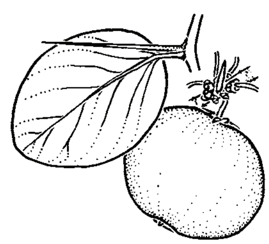
***D. rhamnoides* (Cape cranberry)** This South African shrub produces an ovoid berry that is orange to scarlet when ripe. It is good tasting and makes fine preserves. The fruit can be used for making a thin, very tart wine, and has been used for fruit brandy.

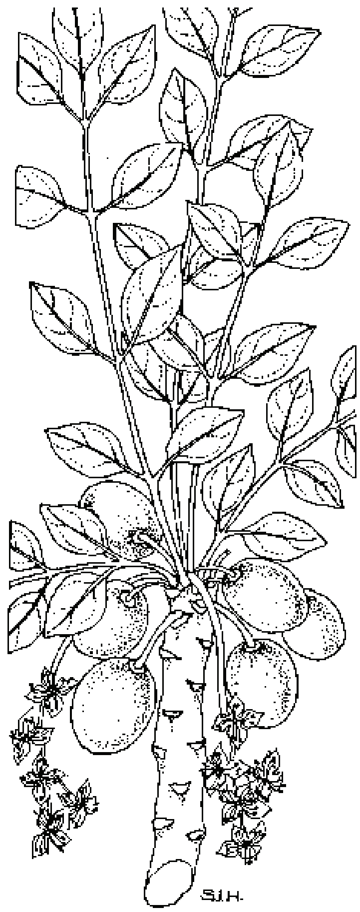
D. rotundifolia Fleshy, bright red fruits sold in the streets of Port Elizabeth and East London in South Africa.

***D. zeyheri* (wild apricot, red milkwood)** Fruit an ovoid berry turning orange to red when ripe. The flesh is sour and strongly flavored. The tree reaches 10 m the leaves are long and lanceolate, the flowers white and delicate. The fruits are described as astringent when raw but good for jam.

Interspecific Hybrids Two hybrids between *Dovyalis* species are known. One appeared at USDA-Miami in 1951 when a female plant of *D. abyssinica* was pollinated by a nearby male *D. hebecarpa*. The progeny (sometimes called Florida gooseberry) are more vigorous, productive, and cold tolerant than either parent. The plants form massive mounds of vegetation (up to 4.5 m high), with all the branches weighted down with excessive crops of the brown fruits. One practical disadvantage is that when the fruit is picked its calyx remains on the plant. This leaves a cavity in the base of the fruit, making it unmarketable as a fresh fruit. However, it can be used to make syrup, jam, or other preserves.

This natural hybrid has been distributed by the USDA as seedlings of P.I. 112086, *Dovyalis abyssinica*. The seedlings show considerable vigor, with many producing heavy yields of large-size fruits. The plants either produce perfect flowers or male and female flowers on the same plant. The fruit is yellowish brown in color and less acid than the kitembilla. Selections have been made and are being propagated by layering or grafting on seedlings of *Dovyalis hebecarpa*. The fruit is used like other *Dovyalis* species.





Sclerocarya birrea subsp. *caffra*

7

MARULA

Not for nothing is marula (*Sclerocarya birrea*) dubbed "food of kings."[1] In the giant triangle from Cape Verde in the west to the Horn of Africa in the east and to the Cape of Good Hope in the south, its prized fruits and macadamia-like seeds are in demand. Many Africans consider a gift of marula nuts a sign of signal friendship. In some societies, the tree ranks as a major food supplier, its economic and social importance being such that they are said to have a "marula culture."[2]

Marulas are plum-sized stone fruits with a thick yellow peel and translucent white flesh. Many are eaten fresh but most are processed into things such as beverages, jams, and jellies. Although the succulent pulp has its own flavor, writers searching for a frame of reference have variously described it as being like litchi, apple, guava, or pineapple. Regardless of taste, the juice is nutritionally important, containing as much as four times the vitamin C of orange juice.

The kernels inside the stone that is found at the center of the fruit are also eaten. They too have high nutritive value, not to mention a delicate taste and such exceptional oil content that they burn like a bright candle. These nuts provide tasty sustenance for both human and beast.

Given these products, marula is at once a fruit tree and nut tree—a sort of tuck shop on a trunk. It is also a good food-security resource. Especially significant in this latter regard is the fact that it provides food during the season when grain stocks are low and other crops have yet to reach harvestable form. It is also significant that the nuts store so well they provided nutritious food long after all else is gone.

The living tree is remarkable in its own right. When fully grown it is large and shady. People genuinely like having it around for its shade and beauty as well as for its fruits. When farmers clear the land, these trees are often all they leave standing. Marula has long been also planted deliberately.

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[1] This is a common Bantu description of marula. It is, for instance, the name given it by the Tonga, who live in Mozambique as well as in the neighboring parts of South Africa and Zimbabwe.

[2] This has been said of the Phalaborwa, for example. Krige, E.J. 1937. Note on the Phalaborwa and their marula complex. *Bantu Studies* 11:357-366.

Oshakati, Namibia. Throughout much of Africa marula fruits and seeds are in high demand. In some regions, the tree ranks as a major food supplier. The large and spreading tree is treasured for its shade and beauty, not to mention its foodstuffs. This is an exceptionally drought resistant species, and its resistance to heat, harsh sunlight, and difficult conditions is legendary (Klaus Fleissner)

It grows with great vigor. It thrives under exceptional heat. And it tolerates some of the most inhospitable terrain known to horticulture.

Marula fruits are not picked: they harvest themselves by conveniently falling off while still green and hard. They hit the ground without bruising, and subsequently ripen within about five days. It is common for farmers to build elaborate fences or to pile thorny branches around their trees to keep animals from reaching the fruits first.

Although when fully ripe the pulp turns pleasantly sweet-and-sour—something like an orange—most of the fruits tend to be tart. Some marulas come with a slight turpentine aftertaste, a feature not universally admired. The scent is applelike and rather pleasant, but can become overpowering where there are large quantities of over-ripe fruits.

But few of these fruits are eaten raw. Most end up in various kinds of drinks. Adding the juice to water, for instance, produces a refreshing squash. If set aside for a few days this liquid ferments into a hard cider. Although both tasty and nutritious, the result can be also highly intoxicating. Marula-juice beverages—both soft and hard—have been commercialized in South Africa. The amounts produced are surprising (at least considering that this is a "lost" crop and as-yet is little grown in organized production). In a recent year, for instance, about 500 tons of marulas were commercially processed for juice and 2,000 tons for liqueur just in South Africa. Beyond drinks, the

fruit is popular for amber-colored jellies. These are so treasured that purveyors charge gourmet prices and peddle them to upscale food fanciers.

Marula is in the same botanical family as cashew and pistachio (not to mention mango) and, like those famous relatives, could become a widely grown nut tree. Indeed, the kernels inside the seed are often more sought-after than the flesh around them. In flavor, they resemble macadamia, and are considered a treat special enough for serving revered guests. Furthermore, marula nut is nutritious enough to outscore even southern Africa's acclaimed mongongo nut.[3]

An important feature is that marula seeds keep for months without deteriorating (at least if clean and completely ripe). Throughout the plant's range, and especially where cereal crops grow unreliably, piles of them can be seen in the villages as emergency food caches. As long as the seeds remain dry, they stay wholesome: neither fungi nor insect are capable of penetrating the rock-hard shell.

As earlier noted, the kernels are rich in oil, averaging about 55 to 60 percent. The oil itself is high in unsaturated fatty acids, typically containing 70 percent oleic acid and 8 percent linoleic acid—excellent numbers indicating an elite vegetable oil.

Beyond good lipids, the kernel contains considerable amounts of protein (23-31 percent). The nut also provides minerals such as calcium, magnesium, phosphorus, and (to a lesser extent) potassium and sodium.[4]

Given all these nutritional components, marula nuts could be a big-time commercial resource—perhaps even globally enjoyed like cashews. However, breaking them out of the shell is a major problem. The seed's woody outer coating is both thick and hard, making the nuts difficult to extract intact.

Although the plant yielding this wealth of foodstuffs occurs over a range of southern and tropical African habitats, it is concentrated mainly in patches of hot, dry, open woodlands. It comes in two distinct types: one indigenous to the southern region is botanically known as subspecies *caffra* and the other, native further north, is subspecies *birrea*.[5] The southern type constitutes the main subject of this chapter. More limited in location, it is nonetheless more developed as a crop.

Although not domesticated in the standard sense, marula is indeed cultivated. For hundreds of years, Africans have planted it, and in places its distribution overlaps almost perfectly with human migration patterns. In

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[3] Marula nuts can produce up to 750 calories per 100 gm, compared with about 640 for mongongo nuts. They also have higher protein and fat contents. Compared to mongongo nuts, of course, marula nuts are less abundant, harder to extract, and much smaller in size.

[4] Wehmeyer, A.S. 1966. The nutrient composition of some edible wild fruits found in the Transvaal. *South African Medical Journal* 40:1102-1104.

[5] There is also a subspecies *multifoliata*, which is intermediate between the two. It is found in Tanzania and probably Kenya.

Marula soaks in the unrelenting sun of arid climes, where it grows with great vigor. It thrives under exceptional heat and tolerates some of the most inhospitable terrain known to horticulture. Marula fruit can be eaten fresh but most is made into beverages, jams, and jellies. The flavor is described as being tart, sweet, and refreshing, with a similarity to apple or pineapple. The kernels inside the seeds are often compared with macadamia nut. (Elaine Solowey)

other words, people liked it so much they carried seeds with them and planted it along the wayside as they went. Moreover, in countries such as Namibia, the majority of trees that appear to be scattered around in the wild are actually owned by particular families. And the fact that the trees are mostly females indicates a human influence, because only females bear fruits. The practice of growing elite genotypes from cuttings is part of traditional knowledge as well.[6]

Given such features it can be said that marula (i.e., the southern type) is at least on the first rung of the ladder to domestication. Moreover, horticulturists in South Africa have selected and cloned superior types over the past 25 years. Indeed, some of those clones are entering intensive cultivation in both South Africa and Botswana. This crop is also undergoing trials and horticultural development at introduction orchards established at four locations in Israel's Negev Desert.

There are good reasons for thinking marula worthy of further development. For one thing, the species can be extremely productive. In South Africa, as many as 91,000 fruits have been counted on a single tree in a good year.[7] In Namibia 4.5 tons of fruit have been measured in single season on a single large tree.[8]

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[6] Information from Pierre du Plessis.

[7] This figure is in Quin, P.I. 1959. *Foods and Feeding Habits of the Pedi*. Witwatersrand University Press, Johannesburg. This is by no means an average yield, however.

[8] Information from F.W. Taylor and N. Baker.

For another, shelling the nuts provide work for thousands of rural women with hardly any other source of income.

And for a third, there exists considerable commercial demand for both fruits and nuts. In Namibia, Botswana, Zimbabwe, and South Africa, many fruit are collected and sold by villagers to the rising number of facilities that have been established to process marula, with some handling over 1,000 tons of fruit a season. Pulp is already appearing in mainstream commerce in the form of juices, jams, jellies, puree, and liqueur. Oils are also extracted from the nuts and put into pricey skin products, a process pioneered in Namibia, which even exports marula oil for this purpose.

PROSPECTS

Presently marula is considered a subtropical crop of limited adaptation but considerable promise. Both its adaptation and commercial possibilities may soon be much clearer because the rising popularity of a fruit-juice drink and a liqueur has stimulated horticultural interest all across southern Africa. Although the fruit's clingstone quality means that it is best for processing into such things as juice, jelly, and beverages, its pleasant apple-like odor and litchi-pineapple-guava flavor, not forgetting its nutrient content, would seem to justify confidence in its prospects for much wider use.

Within Africa

How well the southern marula will do in the other parts of Africa is presently unknown. Possibly it will perform in stellar fashion. Here are likely scenarios.

Humid Areas Uncertain prospects. The southern subspecies appears ill-adapted to high humidity. The northern counterpart, however, is a possible new resource for hot and hard conditions. Already, it is being planted quite extensively in Zambia.

Dry Areas Excellent prospects. Marula tolerates saline water and grows with vigor in desert heat. The trees continue bearing even during droughts, although dryness makes the fruits somewhat smaller. Once established, however, the trees are almost never killed by desiccation.

Upland Areas Uncertain prospects. The plant is somewhat frost-tender, but there may be locations where it safely fits the climate.

Beyond Africa

How well this plant will perform and how well its fruit and nut will be accepted in lands beyond Africa is unknown and uncertain. Nonetheless, small-scale trial plantings are warranted in locales to which it is suited.

Marula fruit pulp serves as a flavorful natural base for fruit soft drinks, nectars, and teas; alcoholic beverages such as brandies, liqueurs, beer, wines and punches. Marula is already also appearing in commerce in the form of juices, jams, jellies, puree, and liqueur. (Cori Ham)

USES

Marula primarily provides fruits and nuts, but those are really just a start. Consider the following.

Fresh Fruits The fruits are eaten fresh in many parts of subtropical southern Africa. They are sometimes cooked. The juice not only makes an agreeable drink; it is often boiled down into thick black syrup, used mainly for sweetening sorghum gruel. The flesh can also be dried and stored for later use, when it is typically added to cereal porridge.

Processed Foods Drinks made from marula are everywhere popular. Many places boast of their local marula beer.[9] In southeastern Zimbabwe, for example, it is called "mukundi" and it is much liked. In Swaziland, a very potent marula drink is so popular it drastically affects the local

[9] The fruits ferment so fast there is a common belief they intoxicate wildlife. However, this is now thought possibly untrue or even a ploy to entice tourists. See, for example, de Klerk, W.A. and T.G. Watson. 1974. Baboons and marulas. *Custos* 3(9):33-37.

breweries' beer sales during the fruiting season. In Namibia there is an official marula wine season during which no one is allowed to carry traditional weapons and crimes are punished with double the usual punishment. A distillate for the more sophisticated palate has been developed in South Africa. An "Amarula Cream" liqueur is now available not only in local markets but in international trade.

Nuts Marula nuts are used to flavor dishes of meat, greens, and porridge as well as being pounded into flour and pressed into cakes. The kernels can also be used like walnut or pecan in baking. They are especially used to provide protein and dietary energy during the "hungry season"—the time before the staples can be harvested.

Vegetable Oil The oil extracted from the kernel has a fatty acid profile similar to olive oil. It is not only high in monounsaturation, but is relatively low in tocopherol and thus has exceptional stability. On the basis of its chemical makeup, marula oil is well suited for use in frying, cosmetics,[10] or coatings on foods such as dried fruit.[11] Presently, it is too expensive to succeed as common cooking oil, but might find a niche market as a specialty salad oil. It may also find greater use in cosmetics; it is "non-drying" and reportedly seems to have properties that combat the aging of skin. Because of its reputed antibacterial action marula oil is used to treat wounds and burns. It is also used as a preservative for biltong (dried meat).

Forage Stock farmers love having marula trees dotting their property. This big, leafy tree provides great shade and its fruit, leaves, and bark make excellent fodder, especially welcome during times of drought. For wildlife, the marula is also important, constituting a living, renewable pantry for hordes of herbivores and omnivores—from elephant, rhinoceros, giraffe, and kudu to warthog and hedgehog. Baboons are particularly fond of picking up the ripe fruit scattered under the trees.

Flowers Flowers produce nectar in quantity, making the tree an important resource for beekeepers. The honey is light-colored with excellent flavor.

Wood The wood hardens as it seasons, eventually becoming durable and strong. Although dirty white, with red and brown streaks, it turns a pretty pink when polished. Carvers make it into drums, stamp-blocks, troughs, spoons, stools, bowls, and more. Because it is easy to work and does not splinter, it was once popular for toilet seats—so popular in South Africa that the tree almost became a threatened species.

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[10] Information from Cyril Lombard, CRIAA SA-DC, Namibia.
[11] Burger, A.E.C., J.B.M. de Villiers, and L.M. du Plessis. 1987. Composition of the kernel oil and protein of the marula seed. *South African Journal of Science* 83:733-735.

Other Marula root brews have renown as antimalarial tonics. In some villages, parts of the tree are apparently employed against lice.

NUTRITION

Although marula fruit pulp is an important source of micronutrients, vitamin C is what makes it nutritionally interesting. The flesh commonly contains 180 mg vitamin C per 100 g, but the concentrations can go even higher. In this regard, the marula outshines orange, grapefruit, and lemon. At 2 mg per ml of juice (about the amount of juice found in one fruit), it is an especially important source of this essential nutrient.

Carbohydrate levels of between 7 and 16 percent have been recorded in the fruit pulp.[12] The carbohydrate consists mainly of sucrose, with smaller quantities of glucose and fructose. The acidity is due mainly to vitamin C (ascorbic acid) and citric acid.[13]

Nutritionally speaking, marula has something oranges lack—a good-tasting nut. Rich in food energy, the kernel normally contains around 700 calories per 100 g and surpasses the nutritive content of globally famous nuts such as almonds, chestnuts, and hazelnuts.

Because of their fine taste, marula nuts are described as a delicacy. Their fat, protein and mineral contents make them a useful dietary supplement during winter or droughts. They are exceptionally nutritious, with 28-31 percent protein, 56-61 percent oil, 2.02 percent citric acid, malic acid, and sugar, phosphorus, magnesium, copper, zinc, and B vitamins (thiamine and nicotinic acid). Protein levels of 54-70 percent have been reported for defatted nutmeat.[14]

HORTICULTURE

Seeds mature (inside the fruits) in late summer, and, after a few months of dormancy, are easily germinated if subjected to heat (around 30°C) and moisture.

Vegetative propagation is in its infancy, but Israeli horticulturists have found that propagation via root cuttings is very easy.[15] Such techniques can be used to clone elite specimens as well as to avoid the long juvenile periods that growers of seedlings must suffer. The plant can also be propagated by

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[12] Jaenicke, H and M.K. Thiong'o. 2000. Preliminary nutritional analysis of marula *(Sclerocarya birrea)* fruits from two Kenyan provenances. *Acta Horticulturae* 531:245-249.

[13] Weinert, A.G.I., P.J. van Wyk, and C.L. Holtzhausen. 1990. Marula. Pp. 88-115 in Nagy, S., P. Shaw, and W.F. Wardowski, eds., *Fruits of Tropical and Subtropical Origin*. Florida Science Source, Lake Alfred, Florida.

[14] Burger et al., 1987, op. cit.

[15] Information from A. Nerd.

jabbing sections of large branches into the ground during the wet season. These so-called truncheons are usually about 2 m long and 10 cm in diameter, and are planted 60 cm deep. If cut at the time of bud swelling they strike readily, putting out abundant roots with speed and vigor.

Grafting branch wood from one plant onto seedling rootstocks of another (using terminal grafts) is reportedly very successful. The operation is made just as new spring growth is beginning. Such grafts, covered with sealant, have resulted in almost complete success (98 percent with one cultivar).

Marula trees in general have few pests or diseases. Indeed, they are thought to be infused with insecticidal ingredients. However, a pesky fruitfly invades the ripe fruits, which are also attacked by the caterpillars of at least two moth species.

HARVESTING AND HANDLING

By and large, the fruits are easy to handle because they are firm when they fall from the tree. At that point the skin is tough enough not only to resist bruising from the fall but to give the fruit a good shelf life. Observations in Israel indicate that although different trees drop their fruits at different times, each drops 80 percent of its fruits within two weeks.

Yields can be outstanding. As much as a ton of juice has been obtained from the fruits from a single tree. The juice can be separated by standard techniques, such as the rack-and-cloth press method. Using modern technology, the South Africa's National Food Research Institute has developed a process for making marula juice on a large scale.

Not unexpectedly, storage temperatures affect the way the fruits ripen. In tests, fruits kept at 12°C and at 20°C developed a yellow color and were suitable for juicing. Those stored at the higher temperature were the ripest. They had a deeper yellow color, a higher juice content, and lower acidity. Fruits kept at 4°C remained green and firm for 14 days, and seemed undamaged, but after five days at room temperature (20°C) they developed brown spots and an off-flavor.[16]

The nuts, on the other hand, are difficult to handle. Shelling the peach-stone-like seeds and extracting the kernels inside is almost an art. Some experienced locals use thorns for the task; others employ special metal, wooden, or bone "teaspoons" or extractors (often even suspended from a necklace in marula season) after they have opened the seeds—either by bashing them between two stones, or by chopping off one end against an axe. They become quite deft at winkling the kernels out; boiling or lightly roasting the seeds makes the whole process easier. Boiling causes the cap sealing the embryo chamber to expand so it can be more easily removed, while roasting makes the stone so brittle that striking it makes the caps jump out to expose the kernels inside.

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[16] Information from A. Nerd.

LIMITATIONS

Marula fruits and seedlings are favorites of many animals; all plantings therefore need careful protection. In southern Africa, elephants are among the principal seed-dispersing agents. Elephants also sometimes debark trees, which nonetheless heal themselves well. Giraffe and antelope (notably kudu, and nyala) also browse both leaves and fruits. Goats are such a serious threat to young trees that no self-sown seedlings are found anywhere near villages.

Although most people consider the fruits delicious**,** some are disappointed that there is not more pulp and *less* juice. This could be corrected through selection, but supreme juiciness is also a virtue. Clearly, it depends on what one wants, likes, or expects.

A more serious limitation is that fact that the flesh adheres firmly to the stone. As in mangos or the peaches of earlier times, soft fibrous strands attach the pulp to the stone. The size of the stone is another flaw; it is quite large for the overall volume of the fruit. In addition, the thick skin detracts at least a little from the volume of pulp.

Given that most marulas are currently planted from seeds, there is a long delay between planting and production. This is a major limitation to new plantings, which is avoided with clones.

The ripe fruits can have a strong smell, which one either likes or dislikes. In over-ripe specimens, fermentation can make it worse.

Although the nuts have exciting promise, a major problem is their relatively low productivity. The kernels are small compared with the size of the woody shell around them. As a result, stones weighing 1 ton yield only 40 kg oil and 40 kg edible protein.

NEXT STEPS

This species seems a great resource for alleviating poverty and diversifying rural livelihoods. It has a recognized commercial value and it keeps people and animals alive by providing vital nutrients during times of famine. However, although it is not quite a “lost” crop, there are still many uncertainties about its products and vast unknowns about its performance. This opens different research opportunities, not all of them requiring professional researchers. The following highlights areas of need.

Commercial Development For this much-beloved plant, achieving greater production lies less with science than entrepreneurship, motivation, and investment. The horticultural side is relatively straightforward; processing is in need of some work but it is also basically in hand. However, the market remains underdeveloped and still needs lots of development.

Marula need not be grown only in orchards or for strictly commercial ends. Indeed, it represents a major income opportunity for rural communities throughout Africa, and development work should focus on systems that will

Although oils are extracted from marula nuts and put into pricey skin potions around the world, currently marula's juicy pulp yields the most commercially successful product–a cream liqueur. Whole fruit is collected from the veld by local villagers, providing them seasonal income. Next, skin and stone are separated from the flesh, which is then carefully fermented like grapes. The resulting marula wine, mixed with fruit solids, is distilled in copper pot-stills and matured in small oak casks for about two years, capturing the unique flavors of marula in concentrated form. The final step is blending the liqueur with fresh cream. The result is a smooth, stable, luscious cream liqueur marketed in about 150 countries. (Distell Group Limited)

facilitate community-level production. Nonetheless, bigger commercial markets will provide income opportunities for rural producers lacking the space or capital to plant thousands of trees for commerce. And beyond that, marula can contribute to rural development on many levels, not to mention nutrition and food security for people lacking the money to buy food.

Fodder This is one of the most ancient of all fodder trees and yet the leaves' feed value is all but unknown. Needed now are standard nutrient analyses. These are often an excellent way to get a crop developed. Practical

developments are likely to follow spontaneously, as farmers with livestock are exceptionally motivated to follow up on promising forages because for them no feed means no livelihood.

Selection As far as commercial progress is concerned, this is the most powerful area for research endeavors. Further selection of outstanding wild trees for production of fresh fruit, processed fruit products, and nut is needed. A larger fruit having a smaller stone and perhaps a thinner skin would obviously be more desirable for most purposes. Also, selections with improved precocity and higher yield would be most welcome.

Vegetative Propagation Cloning, including truncheons, is key to making this crop work. For one thing, it improves fruit quality and dramatically reduces the delay between planting and first harvest. The techniques seem to be on hand already. For instance, hardy but inferior fruited trees can be used as rootstocks for selected scions of superior plants. Needed now is engagement by the nursery trade and amateur horticulturists so that top selections become widely available to backyard and orchard-level growers.

Control of Pests While this plant is not normally pest ridden, reliable methods for combating marula fruit fly (*Ceratitis cosyra*, also a mango pest) would strengthen its future.

Food Technology Many food technologies remain to be applied to marula. A key one is the processing of the nuts. Practical methods for extracting the kernels need to be developed. They need not involve a high-tech decorticator. A cheap and simple—but still relatively labor-intensive technology suitable for rural homesteads—would be ideal. Rural women could then decorticate their own seeds in their own time.

Genetic Development There seems to be much genetic variation in the species, and this is a good time to establish gene banks wherein differences between promising specimens can over time be observed and exploited.

It is difficult to prefigure a crop's future direction, but four possible directions have been especially suggested for developing marula by combing through the existing germplasm and selecting types whose fruits are:[17]

- Large (over 80 grams) with good taste and thick pulp (for use as fresh fruit and for making fruit leather and marmalade).
- Very juicy (for things such as nectar, syrup and fruit drinks).
- Rich in sugar (for production of alcoholic drinks).
- Large-seeded (for oil production)

[17] These suggestions are primarily from one of our contributors, Elaine Solowey

In addition to the selection and propagation of superior individuals, it is valuable to alter the sex ratios in the stands, from the usual male predominance to roughly one male to five females.

Reforestation Marula is excellent for revegetation purposes. For instance, in Israel marula is becoming widely planted. For years the Jewish National Fund's reforestation department has distributed saplings for land reclamation, roadside groves, and windbreaks. Nowadays, this small African tree is to be seen binding up scars of deforestation and desertification in many locations.[18] This particular use is poorly appreciated within Africa, where it deserves immediate inclusion in trials and reforestation programs.

Physiology In these early stages of the plant's commercialization, no one knows the outer limits of the marula's adaptability to climate and soil. Tests are warranted throughout much of the African continent. The key finding has less to do with the plant's survival than with its commercial viability.

Phenology Marula could become a great agroforestry species. Rural Africans love the tree and millions would plant more of it on their farms. Needed, though, is a better understanding of the timing of leafing, blossoming, fruit drop, and other seasonal features at various likely locations. The tree's compatibility with neighboring crop plants also needs general assessment. It is especially important to find male plants that provide pollen at the very time that superior female plants are in blossom.

Subspecies performance Botanists have divided this species into subspecies based on observations of visual differences. Now is the time to better understand the true genetic differences and performance requirements of each. Out of this likely will come many surprising and intriguing facts that could greatly enhance marula's use in the hotter, drier, more northern African regions. Perhaps, too, hybrids between subspecies *caffra* and subspecies *birrea* are possible, bringing great benefits to both.

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[18] Information from Elaine Solowey.

SPECIES INFORMATION

Botanical Name *Sclerocarya birrea* (A. Rich.) Hochst. especially *S. birrea* subsp. *caffra* (Sond.) Kokwaro[19]

Family Anacardiaceae, the Mango Family.

Synonyms *Sclerocarya caffra* Sond.; *Poupartia birrea* (A. Rich.) Aubrev.; *Spondias birrea* A. Rich.

Common Names

Afrikaans: maroela, olifantsappel
Arabic: homeid
Bantu: mupfura
Botswna: morul
Burkina: noabega (Moré)
English: marula or elephant plum, morula, cider tree
French: prunier
Mali: kountan, kountango (Bambara); bi (Dog.)
Malawi: mefula
Mozambique: mudângwa (center), canhu (south)
Niger: eedi, diné, dinégna (Sonrai)
Senegal: bire (Wolof), beur, biét (Ouol.); aritj (Sér.)
Setswana: morula
Shona: mutsome, mupfure
Swaziland: buganu (name for both tree and the drink made from fruit)
Zambia: musebe, muongo, msewe
Zimbabwe: mganu (Matabeleland), managahn, bufuna, musomo
Zulu: unganu (which means friend)
Namibia: Omuongo (Oshiwambo)

Description

This handsome, shapely, deciduous tree is often but not always single-stemmed and sometimes reaches 20 m in height. The mature tree's bark is distinctive—rough and mottled in appearance because it peels off in disc-shaped flakes. The compound leaves are aggregated at the end of short branches and blunt twigs. They are pale green on the lower surface and shiny dark green on the upper one.

The species is dioecious, meaning there are separate male and female trees. However, cases of self-fertile hermaphrodite trees producing some

[19] *Sclerocarya birrea* subsp. *caffra* occurs naturally in Southern Africa; subsp *multifoliolata* in central Tanzania; subsp. *birrea* in West Africa and into Tanzania.

fruit have been reported. The female flowers are located at the end of short twigs. One to three flowers occur in a cluster.

The smooth, ovoid fruit sometimes reaches 5 cm in diameter, but is most often about half that size. On average, they weigh 30 g but selected trees yield fruits weighing up to 100 g. As they ripen the leathery green skin turns pale yellow and develops inconspicuous minute rough spots (lenticels). The flesh is white and juicy. The flesh covers a large attached stone, which is usually two-chambered, each chamber containing a seed.

The root system is well developed and the roots are succulent. They store quantities of water and starch, lending tolerance to drought and hard times.

Distribution

Species *Sclerocarya birrea* has a wide distribution in Africa—from Senegal in the west to Sudan and Ethiopia in the north and to the Swaziland and coastal Natal in the south. However, the particular subspecies (*caffra*) that has attracted the most horticultural attention is native only to the southern part of this range, mainly Botswana, Mozambique, Namibia, South Africa, Swaziland, and Zimbabwe.

Horticultural Varieties

A number of improved clones producing large fruits weighing up to 100 g and with a variety of skin colors are known in South Africa and neighboring nations.

Environmental Requirements

This is an exceptionally drought tolerant species, and its resistance to heat, harsh sunlight, and difficult conditions is legendary.

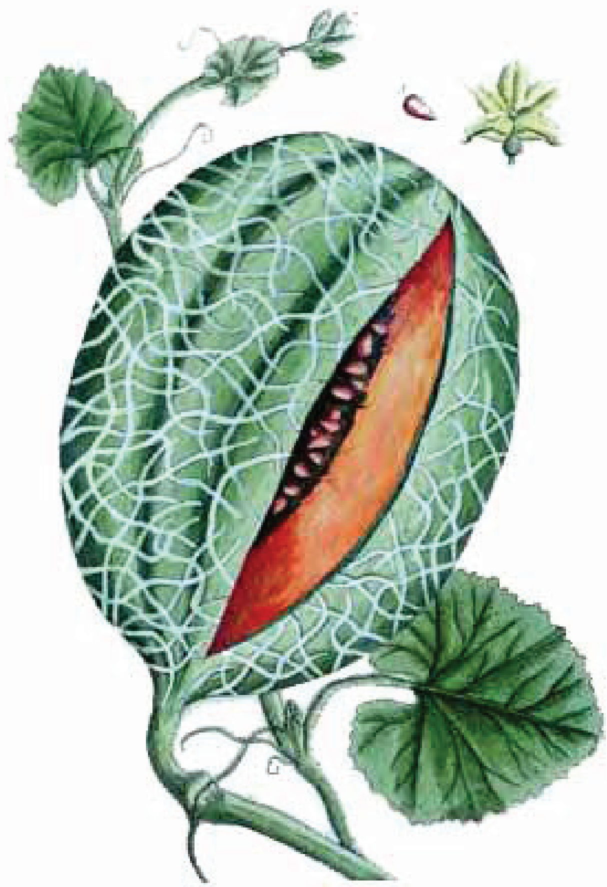
Rainfall Generally speaking, marula is found in arid to semiarid areas with a (mostly summer) rainfall, varying from 250 to some 1,000 mm. In South Africa, the plant is said to be best suited to the 250 to 800 mm rainfall zone. In Botswana, it is found naturally within the 400-650 mm rainfall range. In Namibia, 250-350mm per annum is the norm. The roots store water and the rainfall of the previous season is possibly more important to the harvest than is that of the current fruiting season.

Altitude Low to medium altitude, seldom up to 1,000 m or 1,200 m. The limit is dictated largely by the severity of frost in winter.

Low Temperature Marula grows and bears best in warm to hot subtropical to tropical climates, but (when leafless in winter) can tolerate light frosts. Young trees are more susceptible to frost damage, but even mature trees can be badly damaged by air ("screen") temperatures of –4°C, but it will grow in favored locations in areas with heavy frost.

High Temperature This is a heat-loving crop, remarkably tolerant of high temperatures. No visible damage was observed when summer temperatures rose to 45°C in Israel's blistering Arava Valley.

Soil Swampy soils do not suit this species. Other than that, though, marula occurs on a wide range of deep, well-drained sites from sand to loamy sand to sandy clay (usually sandy loam). Acidity does not seem to be a problem: Analysis in Botswana showed the soil under 13 trees to be pH 4.7-5.5. Nor is alkalinity a problem: marula can become dominant on basalt or dolerite soils in parts of the eastern Kruger National Park. In Israel, the trees showed high tolerance to irrigation with brackish water (EC 32 dS/m).



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MELON

The melon (*Cucumis melo*) is one African fruit that is already known around the world. All the warm regions produce it, and every day millions enjoy a melon for breakfast, lunch, or dessert. Certain countries—among them Iran, Pakistan, Japan, and the United States—look upon themselves as "mothers of the melon," little realizing that the real parent is Africa. Few Americans, Australians, Chinese, Russians, Italians, or Iranians realize that the cantaloupe, muskmelon, or Persian melons on their plates originated from wild (and often impossibly bitter) fruits of Africa's drylands.

Like ourselves, melon is African in ultimate origin. Quite a few species of its genus, *Cucumis*, occur across the continent, and the wild plants that gave rise to today's melon are native in subSaharan eastern tropical Africa. Probably, it was domesticated after other major crops but, when it left Africa, widely different forms quickly arose in various corners of the world.

The crop succeeded first in the drier, longer-season parts of ancient Persia, India, and Southwest Asia (including Egypt); in fact it naturalized in India, which is regarded as a secondary region of novel germplasm. From "Persia" it spread East and West, including all the historic Mediterranean world. It captured the French imagination after reaching there about the fifteenth century; one intellectual produced a treatise enumerating fifty different ways to eat melons, including in soup, fried, or served simply with salt and pepper. The English aristocracy prided itself on the perfect melons their gardeners produced in glasshouses. From Europe, the melon journeyed on westward to the colonies of the Americas.

Melons are reasonably priced and seasonably available across countries that span many climatic zones, such as Russia and the US. While lacking a long shelf life, many varieties are tough enough to ship long distances at cool temperatures. Although most people consider it a sugary nothing in nutritional terms, it can be an important source of some nutrients, especially provitamin A.[1] Combined with its welter of flavors, textures, sizes, and colors, melon is one of the most promising fruits for further development.

Despite its international success, however, the crop is far from being exploited to its fullest, even in the areas that know it best. Indeed, today's

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[1] One contributor did write, "Let's face it, melons are eaten for their taste and sweetness, not nutritional quality. Let's enjoy it for what it is and be happy we have such a luxury."

Melons are high-value products in some parts of the world. Shown here is a small specimen in a Nakatsugawa, Japan supermarket, priced (in 2006) at US$25, next to a $15 apple. In most places, melons are more reasonably priced and are seasonally abundant. High in provitamin A, many have rinds robust enough to handle long distance travel. The scope and complexity of flavors, sizes, flesh colors and textures makes the melon one of the most interesting of all fruits. (Karen Rei Pease)

melons are based on seed carried out of Africa centuries ago (probably by camel caravans moving across the Sahara to Pharaonic Egypt). The true wealth of its diversity was not only left behind, it remains untapped and unappreciated; at least part of it almost certainly remains undiscovered.

This wealth of genetic diversity results from the fact that the melon is perhaps the most horticulturally plastic of all fruits. Few others, if any, can match the range of extreme types that have already been selected. Consider the following range of fascinating features:

Size Some melons found in different parts of the world can weigh as much as 30 kg, so large a normal person can hardly lift one; others are no larger than small plums. A type in Australia is the size of a grape.

Shape Many melons are not round. One, for example, is about 3 cm in diameter and a meter long, coiling in all directions like a spastic snake. An Algerian type splits into sections, like a half-opened tulip blossom.

Color Melons can span at least half the colors of the rainbow: there are types with skins that are red, green, yellow, or mottled; and types with flesh that is red, orange, green, yellow, or white.

Eating Quality Most melons have thin skins and a delicious, melting, honey-like flesh, but some have little or no sweetness at all. Certain ones are hard to distinguish from cucumbers and are eaten as vegetables. One is actually sold under the name "Armenian cucumber."

Other Uses Some melons are grown exclusively for their large, oily seeds, which are roasted like nuts and eaten as snacks. For centuries, "senat" seed was a major export of the Sudan (for more on seeds from various melons, see the Egusi chapter in the companion volume on Africa's vegetables). In Africa, oil is still often extracted from the seeds of the *agrestis* subspecies and used as cooking oil. A number of melon types are used as leafy vegetables, boiled and eaten like spinach.

Nonfood Uses Some melons are inedible. A few are valued solely for their sweet fragrance, and are used as natural air fresheners.

With all these different genetic versions, melons are "designer fruits" *par excellence*. The possible combinations of shapes and sizes, tastes and textures, colors, and culinary qualities that might be fashioned out of this single species seemingly approaches the infinite. Undoubtedly, some of tomorrow's most useful melons have yet to be created. These include types especially suited to African conditions, with qualities such as higher nutrition, more rugged exteriors, longer storage times, greater resistance to pest or plague, greater water-thriftiness or heat tolerance, or any of numerous other desirable genetic characteristics that have already been discovered in this amazingly polymorphic plant.

Even with the limited germplasm on hand, taxonomists have divided the species into at least eight groups, also considered as subspecies.[2] These are:

- Cantaloupensis—the cantaloupe (as defined in Europe);
- Reticulatus—the netted or nutmeg muskmelon; cantaloupe (as defined in the United States);
- Inodorus—winter, honeydew, casaba, or Persian melon;
- Flexucus—snake or serpent melon;
- Conomon—Oriental pickling melon;
- Chito—mango melon, garden melon;
- Dudaim—pomegranate melon, Queen Anne's pocket melon;
- Agrestis—a form grown for its seeds.

It seems probable that once Africa's native melon resources are fully plumbed, this list may have to be revised or expanded, perhaps extensively.

[2] These forms are not the type of variety (cultivar) that represents horticultural selections; they are types found in nature and that are differentiated botanically.

PROSPECTS

Melons are already more popular than most people think. In the U.S., for instance, they are second only to bananas as the most consumed fresh fruit per person. Despite this, though, the melon has a far greater future ahead. Africa's raw genetic resources include many remarkable melons, and dozens of new versions of this well-loved worldwide food are likely to be developed. For another, there are also possibilities for greatly increasing local use in dozens of nations. These robust plants not only adapt well to many different situations, they are fast growing, quick maturing, and extremely tolerant of heat, drought, rains, and other climatic stresses. By and large, melons transport well; a few having six-month shelf lives. Indeed, there is already a growing international trade in melons—some of it by air—and this also seems likely to increase.

Within Africa

For Africa, both the undeveloped local types and the foreign highly developed types have much promise.

Humid Areas Moderate to excellent prospects. In spite of the fact that the melon is now a warm-temperate or subtropical crop, it has potential for the monsoonal lowland tropics.[3] However, it is susceptible to serious fungal diseases (such as *Fusarium*), and it generally does best if grown in the drier seasons when heat and humidity are more reasonable.

Dry Areas Excellent prospects. Melons probably have their greatest prospects in the drier regions. Most require plenty of sunshine and do well in the hot, dry season. For all that, however, they require plentiful water for the best yields of large fruits. Thus, in truly arid areas they must usually be given at least supplemental irrigation.

Upland Areas Fair prospects. This seems to be low elevation crop. Near the equator, however it can be grown at moderate altitude.

Beyond Africa

Although Africa is the melon's center of origin, a secondary region of diversity occurs in Asia—specifically in the region covering Iran, the entire Central Asia area,[4] India, and parts of China.[5] The former Soviet Union,

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[3] In Indonesia, for example, it is commonly cultivated, especially in East Java and along the northern coast of Java.

[4] Ono of our contributors, Henry Shands, emphasized that all Central Asia has great melons: "I have screened melons from Uzbekistan, Turkmenistan, and Kazakhstan and they all have extensive and impressive amounts of genetic variation in size, shape, taste, sugar, etc."

alone, had more than 1,000 named melons, and Turkey has hundreds…each said to have a distinct flavor.

Perhaps nowhere has this fruit's genetic potential been expressed to a greater degree than in Japan, where melons with elegant shapes and individual aromas sell at astronomical prices and are considered among the most desirable and delectable taste treats.

USES

Melon has many more uses than most people imagine. Consider, for instance, the following.

Fresh Fruits Melons are mostly eaten fresh. The flesh is consumed directly from the rind, occasionally with a little salt, sugar, or maybe powdered ginger. Many Westerners may consume them mainly for breakfast, but in France, they are commonly consumed as an appetizer at the beginning of the evening meal. Most Africans and many others eat them fresh anytime. Melons are also often sliced and peeled to eat with other foods or diced into salads. The fruit may be canned or boiled down into a syrup or jam. A few types are used only as preserves.

Processed Foods Not all melons are eaten fresh. Many are dried into a sweet and tangy form of fruit leather that will store for months or years without deteriorating. In Uganda, for example, ripe melons are crushed, the seeds separated, and the flesh dried in the sun. Later this melon leather is washed and boiled in water until soft, then peanut paste is added. The melon leather also may be cooked with dried fish or meat, to which peanut paste is often added. The resulting fragrant sauce is served with millet bread. In Central Asia, dried melon fruit are also eaten year round.

Water Melons (native or cultivated) are an important source of water in certain regions of Africa. Some are grown in the fields just for consumption by farm workers seeking relief from the heat of the day. This happens commonly in central Sudan, for example.

Vegetables As noted, a number of melons are grown specifically as vegetables. An example is the conomon or melofon,[6] grown in parts of Southeast Asia. Fruits are green with yellow stripes, and much more like cucumbers than cantaloupes. Cooked as a vegetable, they are said to make

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[5] This is perhaps the place where most of today's *cultivated* variants originated. Probably, there was independent domestication for subspecies *agrestis* and *conomon* in China, India and Japan, and for subspecies *melo* in Southwest Asia.

[6] *Cucumis melo* subsp. *conomon*. In English this is usually known as melofon, Oriental pickling melon, or Chinese white cucumber. In Chinese it is ts'it kwa or vet kwa.

an excellent stir-fry. In France, most of the time, cantaloupe muskmelons are eaten as vegetables. Many old local varieties exist but are now unexploited.

Seeds Even the types with inedible fruits have uses. They (as well as many edible types) are grown for their seeds. Beyond being roasted and eaten as snacks, melon seeds yield edible oil. In various parts of Africa this liquid is used for cooking and other purposes; some is even exported to Europe. In past years, for instance, Senegal produced 60,000 kilos of melon oil. In Sudan and Ethiopia it is still commercially important. One type of melon[7] grown specifically for edible seed (senat) once was a major export.

Rind There are melon types that are grown only for the rind, which is used in pickling and preserves.

Other Uses In Cameroon, types with small fruits are cultivated almost exclusively for their edible leaves. The fruits of some cultivars are so bizarre-looking that they are grown for use as household curiosities. The dudaim melon[8] of equatorial Africa is particularly unusual. Its fruit is all but inedible and no larger than a lemon. However, it has a strong and very pleasant smell. It will keep a kitchen or even the entire house smelling sweet and fresh for weeks.

NUTRITION

The edible portion can constitute up to 80 percent of a melon. The flesh contains mostly water (about 90 percent) and carbohydrates (10 percent). The carbohydrate is essentially all sugar. As it grows, the fruit accumulates fructose, glucose, and sucrose.[9] Upon ripening, it softens and its fruity, aromatic essences are formed.

Melons are excellent sources of provitamin A (beta-carotene)—almost as good as mango, with over 3,000 International Units (170 RAE) per 100 grams fresh edible portion. Not unexpectedly, yellow and orange-fleshed melons are the best sources. As to vitamin C, the type known in the United States as cantaloupe contains about 45 mg and honeydew 32 mg per 100 g edible portion, making them a good source of that vitamin as well. Levels of potassium can also be high but highly variable, averaging about 265 mg per 100 g of fresh flesh.

The seeds are good sources of energy and protein. The kernel contains approximately 46 percent oil and 36 percent protein.

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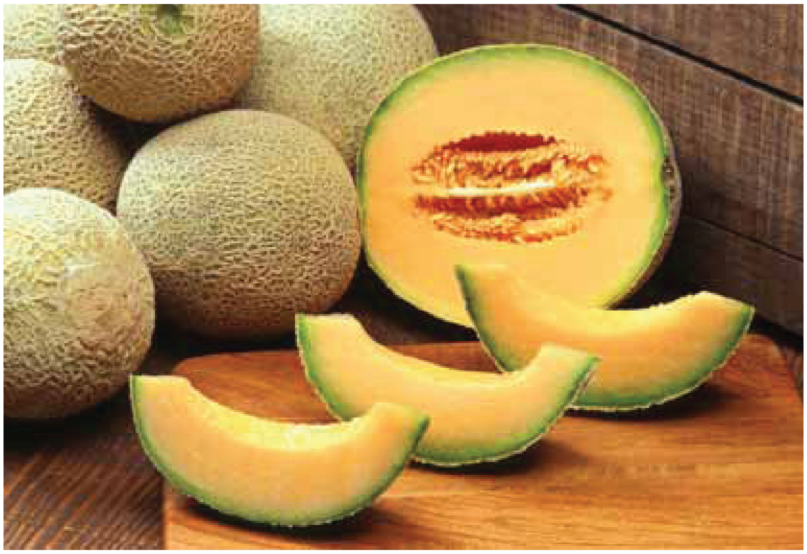
[7] Usually designated *Cucumis melo* subsp. *agrestis*, this type occurs wild in tropical Africa but apparently was not domesticated there; it seems to have came back from Asia.
[8] *Cucumis melo* subsp. *dudaim*. Also known as pomegranate melon or Queen Anne's pocket melon.
[9] As with many cucurbits, the carbohydrate formed in leaves and translocated to fruit is stachyose, a tetrasaccharide. However, the fruit accumulates neither stachyose nor starch.



Today's melons are derived from seed carried out of Africa, probably on the backs of camels swaying northward across the Sahara in the time of the pharaohs. Melon has "quickly" become one of the most popular fruits. They are second only to bananas as the most consumed fresh fruit in the United States, for example. Despite this, melon could have a far greater future in the daily life of millions, especially given all the untapped biodiversity still in Africa. (USDA, Scott Bauer)

HORTICULTURE

Because the cultivation of this crop is so well known we need say little. Melons are propagated by seed, of course. Depending on cultivar and soil conditions, they generally require 85-120 days to go from sowing to harvest.

Pollination is by insects. Male flowers open first and are the more numerous of the two. If insect pollinators are too few, hand pollination can improve fruit set. However, hand pollination is very inefficient and cannot compete with a hive of honeybees.

Yields vary depending on cultivar, planting density, and location. They can be very high. The nationwide average in the United States is 18 tons per ha. Under irrigation a good harvest is 20 tons per ha; without irrigation (but grown on a trellis), 8 tons per ha can be obtained. Perhaps the champion yielder is the Charentais European-type cantaloupe cultivated under glass, mostly on a trellis using plants that are pruned. Production comes in two waves: 25 tons per ha for the first wave, 10 tons per ha for the second. Yields using high intensity "fertigation" can reach *70 tons per ha.*

Melons are grown in very diverse cropping systems, including many in which it is cultivated concurrently or in rotation with a variety of vegetable

and field crops. Some are grown as a means for making unused scraps of soil productive. Javanese farmers, for example, sow the seeds on dikes between rice fields as well as in the land left to rest and recover following sugarcane.

HARVESTING AND HANDLING

Although some melon varieties have excellent shelf lives, most must be handled with skill and care. A few demand special attention because their skins are thin and easily bruised. Once ripe, melons decay quickly and become difficult to handle. Lacking starch reserves, they do not ripen or become sweeter after harvest. For the grower this creates a dilemma, because the later they are picked, the shorter the shelf life but the better the taste. Fresh melons may be stored at cool temperatures.

LIMITATIONS

Melon is still under-collected in Africa and elsewhere. The unusual types are poorly known, and breeding and planting materials are difficult to get.

Many African wild melons are bitter. Some *Cucumis* species are also toxic, although apparently not *C. melo*.

Melon is often susceptible to soil-borne diseases. Heavy losses are often reported because of a premature collapse of the vines. Major causes are fungi, such as fusarium wilt, powdery mildew, and downy mildew.

Numerous insect species can be found on melon plants. Only a few are economically important, but they can be devastating. A major pest is the melon aphid. Others include crickets, cutworms, leafminers, armyworm, loopers, borers, and whitefly—a major and evolving problem.

High-intensity production of high quality melons requires assured pollination by honeybees or other pollinators. Though not usually a problem in subsistence or backyard horticulture, in many places beehives are brought in and placed in or around large fields to ensure pollination. This creates logistic difficulties as well as potential conflicts with control of insect pests.

NEXT STEPS

Research needs of conventional, commercial melons do not concern us here. Beyond the periphery of those pressing problems, however, lie fascinating opportunities that can employ African knowledge and genetic resources to open new horizons for production and use of melons within Africa and without. In this sense, then, there are outstanding opportunities for collaborative research between Africans and scientists worldwide.

Genetic Diversity An international effort to collect melon germplasm should be mounted. Emphasis should be on unusual types. Many of those are of course to be found in Africa. However, to assess fully the germplasm available for breeding programs, types grown in other regions also need

collection. Special examples of these are the landraces of subsp. *melo* (Southwest Asia, Egypt, Arabia, Asia Minor, Russia, and the Central Asian Republics) and of subsp. *agrestis* (Indian Subcontinent, Southeast and East Asia, tropical Africa), and undomesticated material.

Genetic Details One of the mysteries behind this crop is the identity of its wild ancestor. African plants now wild may not be true progenitors. Whether these types originated in that locality or are feral escapes from human control is still an open question. A lot about this worldwide crop could be discovered by the unequivocal identification of wild ancestors and the interrelations of all the various diverse melons now found around the globe.

Better knowledge of the genetics of *Cucumis* species—*C. melo* varieties in particular—would also boost development of all future melons, conventional or exotic. The situation parallels that with *Brassica* species, in which genetic details have been exploited to create new and commercially viable vegetables related to cabbage, cauliflower, broccoli, and so forth. Melon is a similarly plastic species and carries the potential for creating types with strikingly different qualities. And a better understanding of the genome will help scout the routes to an even greater future for the crop.

Melons for Developing Regions Although many improved cultivars have been developed in the United States and other temperate regions, little or no work has been done on improvement of melons for the rigors of field conditions in most developing countries. Plants could be selected whose fruit have less water and more nutritional components, adaptation to tropical climatic and pest conditions, and better fit with local tastes and traditions.

Root Fuel The roots of some cucurbits, especially buffalo gourd (*Cucurbita foetidissima*), are dug and used as "firewood." The possibility of turning melon roots to this end should also be assessed, especially in areas where fuels are in short supply.

Nutritional Improvement There is insufficient work on melon's overall nutritional qualities. A complete assessment of variation in the divergent types is needed. Also, there is great potential for improving nutrient levels through plant selection or breeding. The levels of both vitamins A and C, for example, can likely be increased with targeted research and the selection of individual plants with high levels of these important nutrients. However, the current ones are already good, and programs to take better advantage of the already available germplasm are very much needed also.

Melon Breeding Objectives of melon-breeding programs could be manifold, but might include targets such as improved disease resistance, smaller fruits, better pest resistance, or increased drought tolerance. With

proper research many types of melons can be developed with improved storage qualities. Micropropagation could be used in conjunction with such a breeding program to speed the mass-propagation of rare types.

SPECIES INFORMATION

Botanical Name *Cucumis melo* L.

Family Cucurbitaceae

Common Names

China: heung kwa, t'im kwa
Dutch: Meloen
English: cantaloupe, muskmelon, sweet melon, honeydew melon
Ethiopia: yek'ura-haresa (Am)
French: cantaloupe, melon
German: Melone
India: kharlruz, karbuja
Indonesia: blewah
Kenya: mageye (Swa?) malange (name also used for pumpkin)
Malawi: kayimbe (Ch), mpombe (Y), luwimbe (Ng)
Malay: blewek
Philippines: katimon
Spanish: melón
South Africa: spanspek
Sudan: agur, ajur, fagus, senat-tibish, shammam (Ar)
Tanzania: mageye
Thai: ma-teng-lai
Uganda: akobokobo, akolil (Ts), olujo (Bar), kuluji (Rl)
Zambia: mankolobwe, shikaka, vitanguz (wild cucumbers)
Zimbabwe: spanspek

Description

Melons are annuals with climbing, or trailing vines up to 3 m long. The leaves are usually shallow lobed and more or less rounded. The plants are either monoecious (male and female flowers on the same plant) or andromonoecious (male and hermaphroditic flowers on the same plant). Flowers are fragrant, edible, and usually large. Most are yellow; some white.

As noted, the fruits are extremely variable. They may be ellipsoid to globose, with or without longitudinal grooves. The skin may be soft or hard, yellow, green, cream, or orange in color; and plain, netted, or prickly in texture. The flesh varies from white to cream-yellow, orange, or green. Most of today's commercial types have thin skin and thick orange pulp.

Honeydew is an exception. Most melons are many seeded. The seeds are flattened, and may be cream or light yellow.

Distribution

Melon is grown worldwide. Its exact origin is unknown, but the wild species of *Cucumis* occur in Africa, so it seems clear that it originated there. Melon's primary diversity seems to be tropical and subtropical West Africa, where at least 40 *Cucumis* species are endemic. Many other wild and semicultivated types are found throughout Africa. So too are cultivated types, many of them returnees from Asia, Europe, or the Americas.

Although the melon was introduced into Asia at a comparatively late date, well-developed secondary regions of variation now occur in India, China, Iran, and Central Asia.

Horticultural Varieties

The classification of this highly polymorphic species is confused. A number of species and varieties have been erected from time to time, but this may not be justified as all the forms hybridize readily and there are many intermediate types.[10] The most commonly cultivated types are:

- Cantaloupe melon of Europe (Cantaloupensis group). This has a thick, scaly, rough rind, often deeply grooved.
- Muskmelon (Reticulatus; called cantaloupe in the trade), grown mainly in the United States. This has smaller fruits and rinds that are finely netted to nearly smooth, with very shallow ribs.
- Casaba, Persian, or winter melon. Produces large fruits that mature late with good storage quality. The rind is usually smooth, yellow, and often striped or splashed in green and white. The flesh is firm with little musky odor or flavor. The Honeydew cultivar group, America's best-known winter melons, with ivory skin and green flesh, is of the Inodorus type.
- Vegetable types. As noted earlier, a number of forms, often with elongate fruits resembling cucumbers, are grown in India and the Far East and used as vegetables. These are mostly domesticates of subspecies *agrestis*, and were used in Egypt, Palestine, and throughout the Fertile Crescent from ancient times until about 50 years ago.[11] In recent times they have attracted research attention in Israel and the United States.

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[10] One author put it: "Melons are the despair of taxonomists. The exaggerated friendliness of melons makes it difficult for taxonomists to arrange them in categories with any degree of fixity, but they have bravely tried all the same, though sometimes a new variety has to be assigned to one category or the other more or less by guess and by golly."

[11] A contributor commented on this: "There was an attempt at the University of Arizona to develop a muskmelon for use like cucumbers. I have seed and am evaluating them now. The first crop looked promising. Pickles made from these were excellent. They seemed to be crisper than cucumbers."

Environmental Requirements

Melons tolerate a wide range of environmental conditions but require relatively high temperatures—higher than those needed by cucumbers. Optimum growth is obtained during dry periods with high temperatures, moderate humidity, and little diurnal variation. Large fruited types produce well only if supplied with reasonable water and soils.

Rainfall Usually rainfall of more than 500 mm is required. It should be well distributed during the period of fruit formation. As noted, under humid conditions melons are prone to leaf diseases. In addition, flowering is reduced and fruit quality is affected.

Altitude Elevations below 500 m seem to favor best growth and development, and the conventional types are usually found below about 300 m, even in the tropics. However, melons grow well at 1,500 m in South Africa. In temperate areas, at least, the crop seems restricted by temperature and the length of the growing season rather than by altitude. Certain special types are grown at higher altitudes. For instance, subspecies *agrestis* thrives at altitudes up to 1,100 m in Ethiopia.

Low Temperature The plants are killed by frost.

High Temperature Full exposure to the sun is beneficial; melon plants require plenty of sunshine and heat. Optimum growth is obtained in dry periods with temperatures above 24°C. Although much higher temperatures are tolerated, some fruits (winter melon, for example) often need protection from sunburn. (Dry plant material can be used as a cover.)

Soil Melons produce best on deep, fertile, neutral to slightly alkaline, well-drained soil. The plant is sensitive to acidity. It can grow well on soils poor in nutrients, but prefers light soils well supplied with organic material with a good moisture-retaining capacity. The root system is sensitive to direct exposure to sun.

Daylength For the most part there is no daylength problem in melons, although some cultivars from China and some breeding lines do not set well under shorter daylengths.

Salinity Two salt-tolerant cultivars have been developed in Israel. Both have good fruit quality, appearance, and taste and can be irrigated with moderately saline water or survive in salty soils.[12] The tang of the salt reportedly enhances the flavor by increasing the percent sugar of the fruit.

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[12] S. Mendlinger, D. Pasternak, and Y. De Malach, Ramat Negev Experimental Station, Ben-Gurion University of the Negev.

Related Species

Cucumis is a genus of about 25-35 species, mostly African. They include the fruit we call cucumber (*C. sativus*). Among other African types worth exploring as fruits are *C. metulifer* (the horned melon, see Chapter 5), and *C. anguria* (both cultivars of the West Indian gherkin and wild types).

Tamarindus indica

9

TAMARIND

Tamarind (*Tamarindus indica*) is one of the great trees of the tropics. Its feathery foliage is common from Senegal to Singapore, Suriname to Samoa. Everywhere it grows, people enjoy the curiously sweet-sour pulp found inside its brittle, gray or cinnamon-brown pods. That pulp is sucked out as a refreshing treat, or mixed into myriad drinks and sauces. Its tang especially blends with the fire of chilies, a marriage lending many tropical dishes their distinctively tart, sweetly biting savor. The famous cuisines of South India (e.g., vindaloo) and Java (satay ayam) are good examples. Westerners recognize the tamarind taste mainly from the well-known Worcestershire® sauce, Jamaicans from their world-famous Pickapeppa® sauce. It is also a common "secret" ingredient in barbeque sauces.

History books often say this plant hails from India. The common name, too, derives from the Arabic tamar-u'l-Hind, or date of India. Even the scientific epithet "*indica*" reflects this old belief in its place of origin. But for all this literal association with India, tamarind is actually African. The wild version is a common savanna tree and can be found over a huge area stretching from the Atlantic to beyond the far edges of Central Africa. The capital of Senegal is named for this native favorite, which in the local Wolof language is called "dakar."

This tall legume has long been integral to African culture. For millennia, people have crushed the fruit pulp in water to form a paste, which they then employ for "souring" their bowls of sorghum or millet gruel. Women in the Sahel, for example, slip in some tamarind when making the gel-like porridge (normally called toh) that is a daily staple of millions.

Although its main product may seem like a rather minor food, tamarind has been called a tree of life. In this regard, an important feature is that its fruits can be stored away and served later—especially during the dry season when fresh fruits are scarce or nonexistent. Fulani nomads, for example, preserve the sugar-rich tamarind pulp in the form of sun-dried cakes, which they rely on for sustenance while moving across the Sahara sands.

Modern Africa has been far from backward in advancing this fruit. Already, tamarind-based soft drinks are favorites in many places. In Mali and Burkina Faso, for example, such drinks (both fresh and carbonated) rival the ubiquitous Coca-Cola® in popularity. Among other things, they are

Wild tamarind, Cape Verde. This species is cultivated throughout the tropics, where it is appreciated for its shade as well as for the sweet-and-sour pulp found inside its brittle, gray-brown pods. What is not widely known is that tamarind is actually African. The original wild version can be found over an area stretching from these islands off Senegal to beyond the Central African Sahel. (Peter Longatti)

featured in up-market restaurants. And Mali's own concentrated tamarind syrup is said to sell better than fancy fruit syrups imported from France. The country is itself exporting tamarind drinks to Europe, where they can be seen selling well on the streets and even in the bars of Paris and Rome.

Although the processed pulp has a notable commercial future in sauces, syrups, drinks, jams, and confections, there are also forms that can be enjoyed out of hand. These "almost sweet" types have their own separate future. However, in the short term they are unlikely to become large-scale international commodities because outside their traditional range, people just aren't accustomed to sucking a gummy dark-colored paste from a pod.

The living tree has great value too. It withstands the assaults of city smog and, thanks to a deep and extensive root system, weathers violent storms. It also tolerates the salty air of coastal locales. Its crown of drooping branches bears graceful, feathery foliage, giving it a handsome appearance and making it outstandingly useful for beautifying parks, backyards, boulevards, markets, and country roads. It is a much-beloved shade tree, both on account of its evergreen foliage and its dense crown. In India, for instance, stately tamarinds throw shade over thousands of villages and millions of grateful travelers every day. For these reasons, alone, it holds much promise in tropical reforestation, especially for plantings in places where people live, work, congregate, and crave a spot of refreshing shade.

And the living tree offers many more possible benefits. It is especially promising for reclaiming deforested and damaged lands and restoring them

to health and productivity. In Nigeria, for example, tamarind is used in anti-desertification programs because it has an ability to grow in arid climates and to resist savanna ground fires. In India also, strips of tamarind are planted among forest trees to act as firebreaks. And tamarind trees have notable promise for sequestering carbon from the atmosphere, because they typically stand for centuries—not just because their physiology permits it, nor because they also resist droughts, fires, typhoons, and salt spray, but because people hate cutting down tamarind trees.

PROSPECTS

For all its widespread use, tamarind still remains largely unimproved and unappreciated as a horticultural crop. This is especially true across its African homeland. Indeed, although commercial tamarind plantings have sprung up in Thailand, the Philippines, Indonesia, Sri Lanka, Belize, Brazil, Guatemala, and elsewhere, only India exploits it in a nationally organized way. As a result, India now exports tamarind to the world. The species, however, has promise for vastly increased use in most parts of the tropics. A major portion of its future lies in a range of cultural situations, including subsistence farming, agroforestry, urban forestry, industrial plantations, and plantings established for humanitarian and environmental benefit.

All in all, the tamarind is so superbly adapted to both dry savannas and monsoonal regions that it deserves greater research attention and extensive organized plantings in such locations. It is hardly a rocket-fast grower, but it is resilient, able to thrive in poor soils, and tolerant of abuse from people, pollutants, and powerful natural forces. The fact it meets two great needs of the tropics—food and shade—endears it to the populace of the hot zones. That is why it has already spread so widely without formal help. Incidentally, it also means grateful growers will protect it almost with their lives. And that in turn means that plantings can be permanent and contribute to food security and human nutrition for decades or even centuries.[1]

Within Africa

Long ago, tamarind marched beyond western Africa to find new homes across the continent. Further east, in Uganda for example, there is a broad tradition of mixing it into the local millet porridge known as ugali, and tamarind pulp is sold in almost every market. Still, when considered in Africa-wide perspective, tamarind is a much-neglected resource.

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[1] Many of these ideas, and much more about tamarind, are elaborated upon in a recent monograph, El-Siddig, K., H.P.M. Gunasena, B.A. Prasad, D.K.N.G. Pushpakumara, K.V.R. Ramana, P. Viyayanand, and J.T. Williams. 2006. *Tamarind (*Tamarindus indica *L)*. Fruits for the Future 1 – Revised. International Centre for Underutilised Crops, Southampton, UK; see www.icuc-iwmi.org. Tamarind was also covered in our 1979 report, *Tropical Legumes*.

Mauritius. Although it may appear to be quite a minor food crop, tamarind has been called a tree of life because its sugar-rich fruits can be stored away without refrigeration and safely served weeks or months later—especially during the dry season when fresh foods are scarce or nonexistent.
(Madeleine Philippe)

Humid Areas Excellent prospects. Although considered a dryland species, the fact it thrives in places such as the Philippines, Indonesia, Singapore, Thailand, and Hawaii shows it can have high tolerance for humidity. It is indeed a tree of both parched zones and humid lowlands. Thus there are many parts of tropical Africa into which it could smoothly fit.

Dry Areas Excellent prospects. Savannas are the plant's original African habitat, so the tree is endowed with the potential to perform on seasonally dry, semi-arid sites. Of course, in such locations it grows more slowly than on better watered ones, but its deep taproot and natural ability to shed its leaves when stressed means that it survives even long droughts and lives on to thrive another day.

Upland Areas Limited prospects. Tamarind requires tropical or near-tropical temperatures. Any promise for the highlands would likely be restricted to equatorial latitudes and elevations below, say, 1,500 m, where the climate never falls below freezing.

Beyond Africa

The tamarind, a tree of many uses, has an especially attractive future for producing drinks, jams, and confections on an industrial scale. As noted, the tree adapts so well from dry savannas to well-drained monsoonal areas that greater plantings seem in order for much of the tropics.

USES

People both rural and urban utilize every part of this species: pulp, seeds, leaves, flowers, wood, and the whole tree itself. Among the wealth of tamarind products, the main ones are the following.

Fruit As noted, the pulp is commonly eaten fresh. In addition, it is blended with sugar, and pressed into loaves, balls, or cakes. Even still on the tree this fruit is almost dry, and that alone endows it a long shelf life. Indeed, it may keep almost indefinitely. One preservation method involves pressing shelled fruit into rounded cakes and storing in a cool place. Another entails packing fruits into jars, using alternate layers of whole tamarinds and sugar.

No matter whether fresh or preserved, tamarinds offer many culinary applications: They can be used to sweeten and season foods such as:

- Cereal products—including Africa's many types of porridges, gruels, and pablums (fufu, ugali, toh, ogi, kisra, pap, couscous, and the rest).
- Soups, sauces, chutneys, curries, fish. This is currently the main use for which European and North American countries import the pulp, especially to add to condiments such as steak and barbecue sauces.
- Confections, preserves, ice creams, syrups. Markets in tropical America often carry a sweetmeat of pressed tamarind and sugar. The fruits are also dipped in powdered sugar and eaten for dessert, like strawberry.
- Drinks. Shelled fruits—cooked in syrup until soft and then put through a sieve—are made into refreshing drinks popular across the tropics. "Tamarind-ades" are enjoyed throughout much of Africa (for instance, Sudan, Egypt, West Africa, and coastal East Africa). Some are sold in cans and are even carbonated. Such tamarind beverages are also especially popular in Guatemala, Mexico, indeed most of the American tropics.

Seeds Tamarind seeds are edible, usually roasted or boiled and eaten after shucking the seedcoat. In roasted form they are said to taste "better than peanuts." In composition, they contain about 60 percent starch. In the form of a flour, they are added to cake- and bread mixes as well as other edible products. A purified pectinlike gum useful for stabilizing processed foods is made from them as well. In addition, an oil resembling peanut oil can also be extracted from the abundant seeds.

Other Foods Young leaves, flowers, and baby pods are all agreeably sour, and in some countries are used to season rice, fish, or meat in curries, soups, or stews. Immature pods are also used like common beans: roasted or boiled, and served as a vegetable, pickled, or added to salads.

Fodder Tamarind is a vital fodder tree for arid and semiarid lands. Further, ground-up seeds make a palatable, high protein "concentrate" for livestock feed.

Raw Materials The powder and concentrated juice from the fruit's pulp are promising raw materials for the food-processing industry. Products from the seeds are promising industrial resources too. Purified seed-gum may be used for sizing textiles and paper products; it also has potential as filler for the adhesives used in making plywood. In addition, the seeds yield a semi-drying oil. This resembles linseed oil, and is said to be suitable for making paints and varnish.

Wood The dark, purplish-brown tamarind heartwood is heavy and dense (weighing around 1,000 kg per cubic meter). Strong and termite-resistant, it takes a fine polish and makes excellent toys, tool handles, turnery products, furniture, and decorative paneling. It is very strong and stable and can be used for boatbuilding. It is widely employed in the camel-powered oil presses in remote rural areas such as Western Sudan. Although sold in North America under the name Madeira Mahogany, it is costly and hard to work, and the tree's typically short bole limits its use as sawn timber.

Fuel Tamarind wood is a valued fuel, and it gives off an intense heat. The heat output approaches 5,000 calories per kg. In India it is the fuel of choice for firing brick kilns. The charcoal can be of such high quality that it has long been used to make gunpowder, and it was also a major fuel for producer gas ("gasogen") units that powered many Indian vehicles during World War II.

Ornamental Use One of the world's finest shade trees, tamarind is particularly valued in semiarid regions, where its huge dome of graceful foliage is all that enlivens many a dreary scene. To find this ornamental along a hot, dusty road or a public park is truly a joy.

Miscellaneous Uses In Africa, tamarind is a host of one of the wild silkworms (*Hypsoides vuillittii*). It also is a good host plant for *Kerria lacca*, a shellac-providing insect. The flowers are reportedly a great source of honey. The trees make good firebreaks because the abundant leaf litter and deep shade beneath their dense canopies suppress most undergrowth. Some

parts of the tree supposedly have curative properties, including fungicidal and antibacterial agents reportedly found in various tamarind products. Concentrated doses of the raw pulp are also used as a gentle laxative, and when boiled into a drink is considered good for inflammations. It is also mixed with salt and used to polish brass, copper, and silver. The seed testa can be used in tanning leather, while the seed husks have been found to make effective fish poisons.

NUTRITION

Up to half the pod weight consists of pulp, which contains both sugars and tart organic acids. Though reputedly richer in sugar than any other fruit (30-40 percent), the pulp usually tastes quite tangy. The acidity is largely due to tartaric acid, whose levels sometimes approach 12 percent of the pulp. However, there is much variability among different trees; some fruits are almost acid free, others so sour as to pucker the mouth. Notably sweet cultivars have been selected in Thailand, and these are highly prized.

As the pod ripens its acidity hardly decreases, but sugar levels increase until they more or less match the sourness. Hence tamarind is said to be simultaneously the most acidic and most sweet of fruits.

The dry pulp also consists of about 4 percent protein, and 1 percent fat. Though it contains negligible provitamin A, it is a good source of the B vitamins thiamin, niacin, and riboflavin. While the high acidity might suggest a good antiscorbutic, numerous tests have found that neither the ripe nor the green stages contain significant quantities of vitamin C.

As to minerals, the calcium value—sometimes above 0.1 percent—is reportedly the highest for any fruit. The phosphorus and potassium contents are also unusually high, averaging respectively about 165 and 900 mg per 100 g dry weight. Pods can also be high in iron, averaging about 4 mg per 100 g dry weight. This could make them useful in countering anemia.

The leaves, with a protein content of 3-4 percent, make a vegetable of modest nutritional merit. They are supposedly, however, a good source of provitamin A, calcium, and phosphorus.

The seeds are about as high in food value as maize or wheat. They contain about 60 percent starch, 15 percent protein, 5 percent oil, and small amounts of sugar. The protein is high in essential amino acids.

HORTICULTURE

The tree is easily propagated via direct seeding or transplantation from nurseries. Handled carefully, seeds remain viable for years and germinate rapidly after being scarified or soaked in warm water overnight. These treatments break the dormancy, with good germination occurring in about a week. However, seedlings are inherently slow growers, taking a year or so to become big enough for planting out. Fruiting then begins in 7-8 years.

Outstanding mother trees are propagated asexually, a process providing many advantages. Vegetatively propagated specimens come into bearing within 3-4 years. They produce more fruits as well as more-uniform fruits than seed propagation. Trees also seem to remain smaller—making them easier to harvest and handle. Shield and patch budding and cleft grafting are fast, reliable vegetative-propagation methods used on a commercial scale in the Philippines. Trees can also be started from branch cuttings, and superior clones can also be grafted onto seed-propagated rootstock.

Globally speaking, tamarind trees receive minimal care, and tend to get very large. But in Thailand's central delta they are intensively cropped and kept to convenient size by planting them close together (about 500 trees per ha) and by pruning (which also rejuvenates the fruiting wood). Even though tamarind is something of a "blue-collar crop," Thai orchardists treat it with as much respect as their mango, pumelo, durian, and other quality fruits. They pamper their valuable tamarinds with such "white-collar" treatments as irrigation, heavy manuring, and thorough pest and disease protection.

Tamarind is shade intolerant and does not appear to regenerate beneath its own canopy. Although slow to mature, the trees are long lived. On average they continue fruiting 60 years, but individual specimens may remain productive 150 years or even much longer.

HARVESTING AND HANDLING

Average annual yields vary tremendously, depending on conditions, the inherent quality of the tree, and the care it is given. One review gives average yields from adult trees as 10 to 50 kg per year.[2] Another reports 150 to 200 kg, or about 12 to 16 ton per hectare.[3] A third refers to average yields between 500 and 800 kg for domesticated trees in India.[4] And there are also claims of well-grown trees producing up to 2,000 kg of fruits per year.

If whole pods are for market, they are best harvested by clipping, which avoids damaging the pod's shell. Fully ripe tamarind fruit can reputedly be left on the tree up to 6 months without loss of quality. Eventually, though, they abscise naturally, or are lost to pests, especially various beetles.

The mature fruit has exceptional keeping qualities and is often sold–unshelled but without other protection–in village markets frequently notable for dirt, filth, and flies. Even when the shells have cracked or broken open, the sugary pulp can remain edible several months. Pulp destined for processing is separated from shell, seeds, and fiber before being compressed and packed (commonly in palm leaf mats) for storage, shipment, and sale.

[2] Forestry Fuelwood Research and Development Project (F/FRED). 1992. *Growing multipurpose trees on small farms*. Winrock International, Bangkok.
[3] Information supplied by the Royal Tropical Institute, Amsterdam.
[4] International Centre for Research in Agroforestry (ICRAF). 1992. *A Selection of Useful Trees and Shrubs for Kenya: Notes on Their Identification, Propagation and Management for Use by Farming and Pastoral Communities*. ICRAF, Nairobi.

Tamarind promises to boost rural development in most parts of the tropics. The sour-sweet pulp is very versatile, mixing easily into sauces and drinks. Its tang blends well with the fire of chilies, lending many tropical dishes their distinctively tart, sweetly biting flavor.
(Glenn Kopp, Missouri Botanical Garden)

LIMITATIONS

There are conflicting claims about the need for a long dry spell around harvest time. Some contributors—basing their conclusions on African experience—declare this is a necessity for growing tamarind as a fruit. In humid areas of Southeast Asia, however, orchards receiving more than 1,500 mm of rainfall annually are possibly the most productive anywhere.

For the first few years of life, the young tree needs protection from grazing animals such as goats.

Harvesting the fruit is difficult because the stem connecting the pod to the tree stays tough even when the fruit is ripe.

Although a legume, the tamarind apparently fixes no nitrogen. Nodule-like lumps are often seen on the roots, but active nitrogen fixation has yet to be detected, despite many attempts.

Insect pests can attack the pods, especially any left on the tree for some time. Seeds are prone to insect attack as well. Beetles and weevils are the worst antagonists. Ripe seeds should always be kept in airtight containers.

Most African countries lack the marketing channels and information to develop substantial operations, but those could be quickly instituted.

Not everyone loves this fruit at first sight. In fact, some take a long time getting used to its lowly looks. The pulp is not colorful or immediately

attractive but usually a rather sticky, somewhat fibrous mush, a sight that is not alluring to those who have yet to learn the secret of its flavor.

NEXT STEPS

There is a broad spectrum of focused actions that could help the world take better advantage of the tamarind.[5] Below are just a few examples.

Basic Studies Filipino researcher R.E. Coronel wrote us: "The much-appreciated qualities of the tamarind and its adaptability to different soils and climates enabled it to conquer the tropics in the remote past; the tree and its fruit are still highly prized today. It is therefore all the more surprising that so little is known about tree phenology, floral biology, husbandry, yield, and genetic diversity...."[6] The list could be expanded; there is much to learn.

Selection Few of the tamarinds now growing throughout the tropics result from horticultural selection—they derive from seeds picked up perhaps at random. There is therefore excellent potential for markedly improving the crop. Much variation in fruit characteristics—such as yield, sweetness, acidity, and the size and shape of the fruit—exists in nature and in millions of casual plantings. Some trees bear exceptionally large pods well filled with pulp; others are so lacking in acid they are referred to as "sweet." Superior types such as these should be sought out and vegetatively propagated.

In addition, budsports are common in tamarind. These isolated branches bear fruits different from those on the rest of the tree. Once identified, budsports can be readily propagated asexually to advance the crop.

Germplasm Collections The greatest diversity of tamarind occurs in the African savannas stretching from Senegal into Sudan. There, specimens can be found exhibiting tolerance to waterlogging, persistent drought, extreme soils, high and low pH, and heavy grazing. These unique individuals need to be identified, tested, shared, and generally made available for use.

There are also foreign tamarind collections that offer great possibilities. The Institute of Plant Breeding in the Philippines maintains a large number of accessions. In addition, India, Thailand, and other Southeast Asian countries have recorded many interesting types. The University of Florida has a collection near Homestead. From these, outstanding plants with fast growth, large fruits, and sweeter and juicier pulp are also likely to arise and help transform world appreciation for this overlooked crop.

Windbreaks The tamarind is one of the few fruit trees–because its branches are so strong and pliant–that can be grown in locations subject to

[5] A full range of examples is in El-Siddig, et al. 2006, op. cit.
[6] Information from R.E. Coronel.

the full blast of tropical storms. Its very extensive root system also seems to contribute equally to its unusual resistance to horrific winds. The need here is not so much for research but for demonstrations, nurseries, and programs to educate people and initiate planting projects.

Commercial Development Tamarind's commercial promise may merit plantation expansion throughout the tropics. As long as quality varieties are planted, it should prove to be a profitable crop that, once established, can require little care and provide benefits for centuries.

Husbandry Tamarind horticulture deserves special attention. Very little is known, for instance, about growth rhythms in various parts of the tropics. Pruning and other manipulations could create, for example, low-growing specimens, manageable in normal orchard practice and reachable from ladders. In such ways, tamarind might produce on a more intensive scale.

Reforestation Every person concerned with the greening of the tropics should consider tamarind. The tree is magnificent for bordering streets and highways, for shading backyards, for farm and village boundaries, and for reforesting denuded slopes.

Global Cooling As a tree to combat any greenhouse effect, this evergreen has the advantage that it may grow (and accumulate carbon) for two or more centuries. Unlike many tropical trees, it normally reaches a ripe old age: people resist cutting it because it provides food to eat and products to sell. Moreover, they are grateful because it turns hot, baking streets into shady, cool boulevards. Whole cities and hundreds of thousands of kilometers of roadsides could be planted with tamarinds. Individuals wishing to help an overheating world could hardly find a better tool among the trees.

Harvesting It seems unlikely that plantings of tamarind orchards will increase in any major way until better methods of harvesting are found or developed. For example, pods today are often just knocked off with sticks.

Other This brief chapter can only touch on the myriad things that could make a difference with a crop as versatile as tamarind. An international website could stimulate further developments and keep the world informed of progress. Beyond food, there are medicinal uses as well as industrial and other applications that could appeal to specialists.[7] Documentation of indigenous knowledge–with local participation–on uses and conservation should be undertaken throughout tamarind's distribution. Specific technical aspects deserving research include genetic resources, breeding, agronomy, harvesting methods, postharvest practice, and processing. There are, too, the economics of production and marketing to be explored.

[7] These too are discussed in the Fruit for the Future monograph previously quoted.

SPECIES INFORMATION

Botanical Name *Tamarindus indica* L.

Family Leguminosae (Caesalpinioideae)

Common Names

Afrikaans: tamarinde, suurdadelboom
Arabic: tamar-u'l-Hind
Bambara: tomí, tombi
Bantu: omukooge (tree), enkooge (fruits)
Burkina Faso: bu pugubu
Arabic: tamr hindi
Dutch: Tamarinde, Tamarindeboom
English: tamarind, Indian date
Ethiopia: hemor, homor, humar, komar, tommar (Am), aradeb (T), b/roka, rucahu, dareho, dindie, ghroma, gianko, omar (G/O)
French: tamarin, tamarinier, tamarindier
Fulani: jtatami
Hausa: tsamiya
Kanouri: tamsugu
Kenya: mkwaju (Swahili), ol-masamburai (Masai), epedur (Turkana), roka (Bor), chuzaa, chua (Luo), kinthumula (Ka), muthithi (Meru), orn (Poko), arwo (Tugen), Loisichoi (Njemps)
Malawi: ukwaju, bwemba (Ch), mkwesu (Y), nkwesu (Nk)
Niger: bossé, bossaye (Djerma), djatube (Peuhl)
Nigeria: Icheku oyibo (Ibo), ajagbon (Yoruba)
Peul: dabe, ngatabbi, n'jabi, n'jame, yammere
Portuguese: tamarindo
Senegal: dakar (Wolof)
Somalia: hamar (Som)
Sonrai: Bósso
Spanish: tamarindo
Sudan: aradeib, tamri hindi (Arabic), shekere, kuashi, danufi (Nuba)
Swahili: mkwaju
Tamachek: basoro, bassasu, bochocko, tchimic
Tanzania: mkwaju (Swa)
Uganda: esukuru, esuguguru (leaves, Ts); fruit: e/apeduru (Buk/Kmj/Ts), iti (Bar/Md), chwa (A), cwa/o (Ach/Lng), pitei (Kk/Ach)
Zambia: mushishi (B), mwemba (Ny), b/musiika (To)

Description

Tamarind is a massive, slow-growing, long-lived tree with dark-gray bark and strong supple branches that droop gracefully at the end. It may reach 25 m in height. The trunk can exceed 7 m in diameter but is usually short even in old trees. However, in the wet tropics trees seem to grow taller and can produce a fairly long clear bole. The bark is strongly fissured and scaly on the trunk and smooth on the branches. It exudes a blood-red gum.

In most growing areas tamarind is evergreen; however, severe drought causes massive leaf drop. At flowering, the trees burst with showy clusters of pale-yellow, pink-veined blossoms. These are cross-pollinated, probably by insects (such as, in India, the honeybee relative *Apis dorsata*) and wind, although the flower structure does not exclude the possibility of selfing.

The tree produces heavy crops of fruits, typically every other year. Trees are known still producing fruits at a reputed age of 200 years. Fruits are long, flattish, gray or rusty colored, bean-like pods, usually irregularly curved, sometimes with constrictions in the spaces between the seeds. They contain 2-10 seeds embedded in sticky pulp. At maturity, the shell turns brittle and is easily cracked open to expose the dark-brown, pasty pulp that surrounds hard, shiny, brown seeds, each in a parchment-like “envelope.”

Distribution

This species is a native of the dry savannas of western Africa but it now reaches the southern limit of its range in Mozambique and Natal, where it has become naturalized around Durban.

Tamarind performs so well in semi-arid and humid monsoonal climates that it is already truly pantropical. It is found across South Asia, where traders or travelers introduced it centuries ago. It is also common throughout the American tropics, especially the Caribbean. In Puerto Rico, as one example, it is fairly common along roadsides, around houses, and on hillsides in the dry, coastal regions.

Horticultural Varieties

Many different types exist depending on the form and quality of the fruits. But at present there are few standard varieties.

Thai orchards grow cultivars of a sweet type (*makahm wahn*) named ‘Muen Chong’, ‘Nazi Za’, and ‘Si Chompoo’. ‘Manila Sweet’ is a similar cultivar from the Philippines.

Environmental Requirements

In their native African habitat, wild tamarind trees mostly grow alone, rarely in small groups, sometimes along rivers (which may be seasonally dry) or lakes, as well as in often rocky, lowland-woodland. The species is a

light demander, very sensitive to frost, and withstands drought. Although happy on plains and stream banks subject to frequent flash flooding, it cannot withstand long-term inundation or stagnant waters.

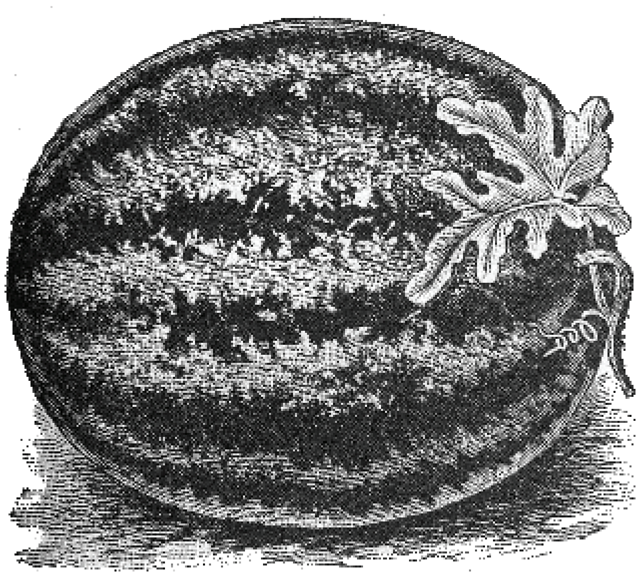
Rainfall In Africa tamarind thrives where annual rainfall drops as low as 750 mm and sometimes below 500 mm. It also can thrive in areas of Southeast Asia receiving more than 1,500 mm. Generally speaking, it seems to avoid regions exceeding 1,900 mm.

Altitude By and large, it is found between sea level and 1,500 m elevation. In the Machakos district in Kenya, for instance, it can be seen growing well at about 1,200 m above sea level.

Low Temperature Tamarind cannot tolerate persistent cold; even brief frost can cause severe damage or death. Anywhere mean annual minimum temperatures fall below about 7°C is too cold to cultivate tamarind reliably.

High Temperature This tree seems undaunted where mean annual maximum temperatures can exceed a blistering 50°C.

Soil Some writers claim tamarind prefers slightly acid (pH 5-5) soil. In Fiji, though, successful growth has been reported in highly acid (pH 4.5) to highly alkaline (pH 8.7) soils. In India, the tree also grows in alkaline soils (pH 8.5). Truth is, this species (or its genotypes) tolerates a diversity of substrates. Although growing best where soils are deep and well drained, it can flourish in poor soils and even rocky terrain. It is also frequently found beside termite mounds or in sands near the seashore. In the Sahelian zone, it commonly grows in association with baobab (see Chapter 2).



10

WATERMELON

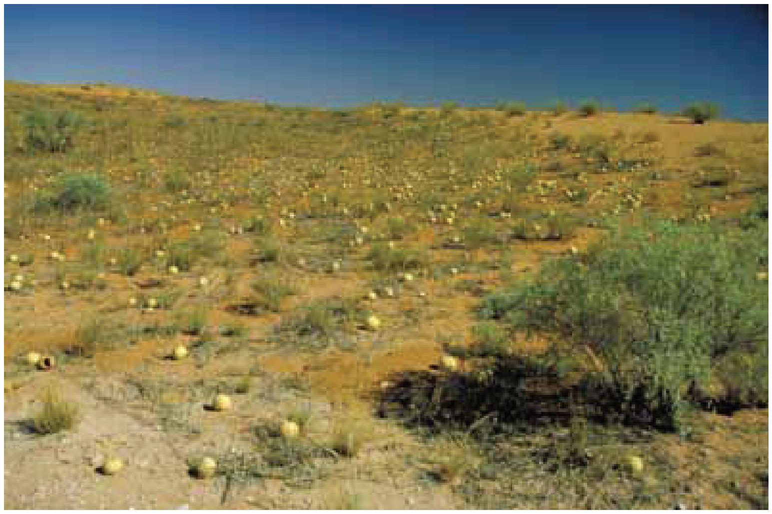
Other than botanists, few people consider that watermelon (*Citrullus lanatus*) is African. Yet this is so: the crop's wild ancestors occur abundantly in the dry zones of the continent's southern region. The African origin may come as a surprise only because watermelon spread around the globe so long ago that for most people it has become part of the wallpaper of life.

Today, this African fruit is cultivated throughout the warmer parts of the world—from the searing tropics to temperate latitudes and even beyond.[1] Global annual production is approaching 100 million tons. Yet Africa scarcely registers in statistics: the largest producers are Turkey, Iran, and Egypt, the United States and Mexico, and–especially–China, which produces over two-thirds of the watermelon in the world. While consumption in the United States has been fairly stable over the past 25 years, elsewhere demand is increasing, and indications for the future suggest ever-greater global production.

Given all this success, it is intriguing to consider that only a few watermelon types emigrated out of Africa. The descendents of those select few rose to a place among the best known of all the world's fruits. With their colorful flesh and luscious sweet juice, they have been called the food of heaven. Mark Twain once wrote, "The true southern watermelon is a boon apart and not to be mentioned with commoner things. It is chief among this world's luxuries, king by the grace of God over all the fruits of the earth. When one has tasted it, he knows what the angels eat. It was not a southern watermelon that Eve took; we know this because she repented."

The homebound watermelon types that remained in southern Africa's arid regions are not at all like that. To naive outsiders they can look like miserable waifs, fully deserving their neglect. But that impression is false. Wild watermelons are useful in their own right, and always have been, their rinds, flesh, and moisture sustaining many inhabitants through waterless times. "The most surprising plant of the South African desert," wrote David

[1] It is abundantly grown, for instance, in parts of Java, providing farmers a substantial income. Major sites for production are also found in the semi-arid parts of coastal Peru and Ecuador. A state-record watermelon grown in Alaska, USA–located above 55° N–weighed 65 kg.



Few people realize that watermelon is African. Yet this crop's wild ancestors are scattered abundantly across the dry wastes of the continent's semi-arid southern hinterland. In Africa's Kalahari Desert the undomesticated watermelons are an important source of both food and water. In times of drought African farmers have traditionally relied on them for emergency use. (© Roland Bischoff / botanikfoto)

Livingstone in 1857, "is the kengwe or keme, the watermelon. In years when more than the usual quantity of rain falls, vast tracts of the country are literally covered with these melons. Some are sweet and wholesome, and others so bitter that they are named by the Boers the 'bitter watermelon.'"

They are also plentiful. Wild watermelons still bespeckle millions of hectares of semi-arid African hinterland. Passersby see them alongside thousands of kilometers of roadsides and bushtracks, particularly in the Kalahari Desert of Botswana and Namibia. But few who spy the tiny nondescript orbs lying amongst scraggly vines beside the road or trail can appreciate that, botanically speaking, they are indistinguishable from the big beloved fruit in their own life. The difference is too great to be grasped at a glance. "This is a salutary lesson in the hidden potential of so many superficially unpromising wild fruits," one of our insightful contributors wrote; "selection and domestication can improve them out of all recognition in a few [plant] generations."

Although their domesticated descendants have been cultivated for over 4,000 years and were old news to the ancient Egyptians, the progenitors that gave them life basically remain strangers to commerce and horticulture. Now is the time to better recognize these orphans of the wilderness. They have value for both direct and indirect use.

Direct Use

African watermelons deserve attention solely on the basis of their own qualities. Many are prolific and productive. They exist on the absolute outer edge of human settlement, where all life is tenuous. They are so important to some people as to literally stand between life and death. And they can be made even greater contributors to the African outback as well as to the world. Examples follow.

Vegetable Watermelon Among all the variants within the species, types with small, hard, unsweetened fruits are among the least developed. In Africa they are grown exclusively as vegetables—cooked like pumpkin or squash. So far, these are unknown to most of the world. In India, though, one type has become a widely used vegetable.[2] Its small, round fruits (up to 10 cm in diameter) look more like bloated cucumbers than watermelon. They are either pale or dark green in color, and are eaten fresh like cucumbers, pickled like gherkins, or candied like apples. The seeds may be dried and eaten like nuts. This type of variant appears to be a crop with considerable potential in its own right…and not just for one nation but for dozens.

Edible-Seeded Watermelon Certain other types are grown solely for seeds. In parts of West Africa—particularly Senegal, but also Nigeria, Niger, Chad, and Cameroon—these are crucial articles of food and of commerce, and are sold in countless markets.[3] The seeds are prepared in different ways. Most are dried, roasted, and eaten as nuts; some are pounded into a paste resembling peanut butter; others are ground and baked into bread, to which they add a nutty flavor; a number are used in soups or stews or parched and eaten with cereal products. The Yoruba of Nigeria ferment the kernel to produce a favorite food flavoring known as ogiri.

Watermelon seeds appeal to more than just local taste preferences, and eating watermelon seeds is not restricted to Africa. West Africa already exports them to France for snack food, to be eaten out-of-hand. Sudan exports them as well. And this is not a new phenomenon: for centuries, Sahelian Africa shipped watermelon seed out of the deserts to populated areas far and wide, including Egypt and beyond. In certain Asian countries, they are also an important snack food. In China's southern province of Guangdong, for example, toasted watermelon seeds are a common fare and an essential part of special occasions, including weddings, funerals, and New

[2] Its common name is tinda, tensu, or tendi. Although botanically called *Citrullus lanatus* var. *fistulosus*, it may not even be a watermelon. Most botanists now claim that it more correctly belongs in a related genus, *Praecitrullus fistulosus* (Stocks) Pang, and say it is unlikely to exchange genes with *C. lanatus*. Even if they're right and this proves not a true watermelon variant, it still is an interesting crop, and one with a bigger future.

[3] These melons normally goes by the name "egusi." The companion volume on African vegetables devotes an entire chapter to the use and potential of their edible seed.

Year celebrations. Indeed, China is yet another nation exporting watermelon seeds, as are India and Pakistan.

Pickling Watermelon In many localities, a hard, white-fleshed form of the fruit is used for pickling and jellies. Known as the citron or preserving melon,[4] this watermelon variety is not edible in the fresh form. It is used exclusively for processing. Each year the United States, alone, employs over 3 million tons of this otherwise inedible fruit to prepare glacé and sweet preserves, both of which are major contributors to the culinary phenomenon called “Christmas cake.” Because of its high pectin content the citron is also used for making jams, jellies, and preserves. The white fleshy rind that occurs between the outer green skin and the inner edible portion of ordinary watermelons is used that way too. Even wild African watermelons are used for a similar purpose: flakes are boiled in sugar to make a tasty jam.

Cooking Watermelon In Botswana the wild fruit is baked in the coals or cooked fresh as a relish. Some traditional types store so well they are still useful for cooking even a year after harvest.

Food Security Such watermelons can be a foundation of the food system. It has been said, for example, that in olden times people couldn’t cross the Kalahari Desert except during a good melon season. These wild watermelons sustained not only the travelers, but also their livestock.

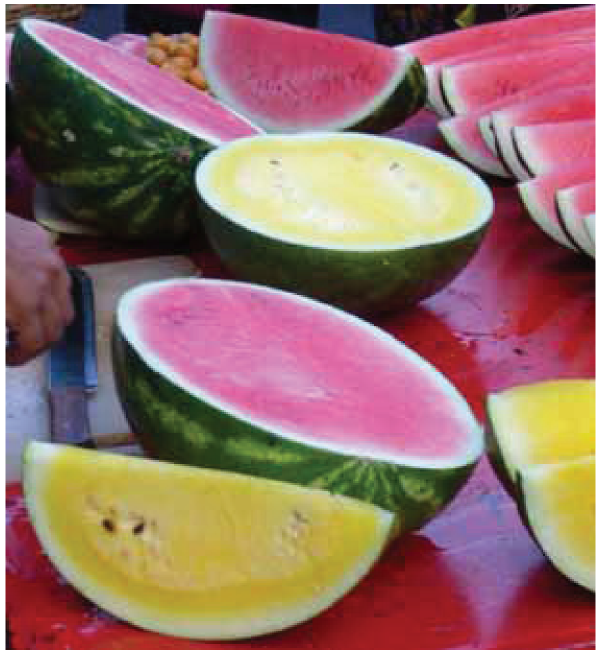
In times of drought, traditional African farmers have long relied on them for emergency use as well. Sometimes the fruits become the sole source of water for their cattle—and even for themselves—for months on end. They also sustain the wild creatures in the Kalahari. Moreover, in addition to leaving the fruits in the desert, people also pile them up near their dwelling as a convenient store of food and water. The fruits keep a surprisingly long time—up to a year in some cases. In such areas, watermelon can be an important source of both food and water, as well as income.

Indirect Use

The ancestral genes to be found in the wild and cultivated African watermelons seem likely to provide tools for creating valuable new watermelons for use around the world, including forms that are presently inconceivable. Although the large green globe with the crimson flesh is likely to remain the main type, some of the changes that could occur in future decades include the following.

Downsizing In a sense, most watermelons today are too cumbersome for convenience. Even the most affluent consumers can barely squeeze one into

[4] *Citrullus lanatus* var. *citroides*.



Though Africa is home, China grows more than two-thirds of the watermelon in the world, followed by the Middle East and warmer parts of North America. Yellow-fleshed varieties, once more common in Europe and the United States, are now surging in popularity throughout Asia, such as in this Chinese market in Yangon, capital of Myanmar. Although the varieties of flesh- and seed-type watermelons already seem overwhelming, scientists have really only begun to tap the genetic diversity available. (Greg Martinez and Francie Zant)

their large refrigerator, some can barely lift the very large fruits, and it takes a big gathering to get one down at a single sitting. Small "icebox" melons–the smaller ones often called "palm" melons because they can fit in the palm of the hand–are becoming increasingly popular in the United States, and even smaller ones are available in Asia—in China, Taiwan, and Japan, for instance. Though watermelons grown around the world are getting smaller, most are still too large (2 to 3 kg) or have other shortcomings such as poor texture, flavor, or durability; vast new markets might open up worldwide if even smaller, very user-friendly types can be developed.

This is not far-fetched, and Africa's untapped watermelon resources could be a key to this. Those wild and feral watermelons can be as small as 2 cm in diameter, and likely contain "downsizing" genes that innovative horticulturists could employ to create fruits of less than 1 kg. The resulting "microwatermelons" might be small enough to be conveniently carried—maybe even in a lunchbox or backpack. They would be cut open only when

eaten, a feature that would end the annoyance of juice dribbling into a lunch pail. They would also end the waste of having half a giant fruit sitting around softening and spoiling. And they could be consumed at a single sitting by an individual or small family—a feature particularly important in homes in hot regions with no refrigeration.

Designer Colors Today's watermelons are, in a manner of speaking, caught in a time warp. They are much the same color as in the era of the ancients: usually green on the outside and red on the inside. A returning Pharaoh would know them at a glance. But this is just one form out of dozens of possible color combinations: watermelons can be yellow or orange on the outside; white, yellow, pink, or orange on the inside; or any mix of those colors, including striped, speckled, or patterned.

Yellow-fleshed types today are actually preferred in parts of Asia. They are gaining popularity in a number of nations and could soon have a global impact. In China, some varieties with orange rinds and golden flesh are already produced on a large scale. Their shiny bright skins and deep-yellow flesh make them extremely attractive. In the United States, too, golden watermelons are showing signs of catching on with consumers.

Seedless Fruits Scattered as they are throughout the flesh, watermelon seeds are generally considered nuisances. They cannot (as in melons) be easily scraped out, and many rules of etiquette exist for spitting seeds. Seedless watermelons have of course been created, but the complex genetic manipulations required are often difficult to perform repeatedly.[5] Another approach is searching among the array of Africa's wild types, seeking variants with edible or inconspicuous seeds. Some of those might bear naked seeds (entirely lacking a seed coat), seeds with soft-coats that are chewable, and there might even be a few with seeds too small to bother anyone. West Africa already has a soft-seed type, known formally as subspecies *mucospermus*, so this path seems to merit exploration.

Unusual Plant Forms Vines are always wasteful of space and awkward to cultivate. A dwarf, bush habit that still fruits on the ground could be extremely valuable to growers. This would be especially so if the plant were not too compact (because the shady dampness beneath a dense canopy tends to encourage diseases and pests). The possibility of such types occurring in the vast genetic wealth within Africa deserves exploration. Other horticulturally useful forms also probably await discovery.

[5] Production generally involves crossing a tetraploid plant (four sets of chromosomes) with a normal diploid (two sets). The resulting triploid (three sets) is sterile and its ovules small and empty of seed. To complicate the procedure even more, a diploid plant must be present to pollinate, fertilize, and trigger fruit-set in the tetraploid pistillate flower.

PROSPECTS

Within Africa itself, as well as for other parts of the world, the watermelon's unprepossessing ancestors have more potential than might be imagined. Considering the genetic wealth to be found in wild African types, even the places that supposedly know the crop best would have to concede they have hardly tapped its many potentials. Further, it is possible that–with or without incorporating genes from wild types–a watermelon rebirth will occur across Africa by returning home with types already known elsewhere.

Within Africa

As we've indicated, watermelon seems to have untapped promise in many parts of the continent, including, in this case, those parts that lie to the north of the Sahara.

Humid Areas Fair. At first sight, the prospects in Africa's lowland tropics are moderate because humidity enhances leaf diseases such as powdery mildew and root rot. On the other hand, though, cultivars bred to resist these fungal afflictions have made Florida and contiguous parts of the humid South the main watermelon-growing region of the United States. Such resistant types hold the key to greatly enhanced watermelon use in the even more fungus-challenged quarters of the globe, including Africa.

Dry Areas Excellent. Because of its deep-roots, watermelon is a particularly good crop for dry season use or drought-prone areas.[6] It is commonly planted as a relay crop in sorghum fields; the species being so drought tolerant that if the sorghum crop—or even the millet crop—fails for lack of water, there still can be a fair harvest of watermelons.[7]

Upland Areas Moderate; perhaps excellent. The prospects here depend on the elevation and the latitude. Watermelon requires a long growing period with high temperatures and much sunlight. For humid sites disease is a concern, and resistant cultivars should be employed.

Beyond Africa

Although many millions of tons of watermelons already are grown each year, prospects for boosting global consumption seem good. One indirect indication of their rising popularity is the observation that watermelon festivals continue to proliferate. The fruit ships well and has a reasonable shelf life. It has been suggested that sweet, small-sized, pink-fleshed

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[6] One contributor wrote, "I have seen it growing well in North Kordofan in the summer surrounded by pearl millet that was dead or dying."
[7] This is done in south-central Mali, to mention just one location out of many.

A roadside watermelon vender holds market in Ghana. Watermelon fruits offer prospects for rural development almost anywhere they can be cultivated because they are generally easy to grow, easy to transport, easy to store, easy to sell, and easy to eat. (Scott Mori)

specimens would find an almost limitless market in Europe. Dried or roasted seed, already popular in parts of Africa and Asia, also has promise for much greater use as a foodstuff.

USES

This is another crop offering multiple products. The edible parts are notably the crisp flesh of the fruits, but also the rinds, seed kernels, tender young leaves, and flowers.

Fresh Fruits Watermelons are of course mostly eaten fresh as snacks or desserts. Many places make a refreshing drink from the juice, often incorporating a dash of lime or lemon juice. In Russia especially, the juice is boiled down into sugary syrup. In Namibia, the juice is fermented into a refreshing, lightly alcoholic drink.

Rind In parts of Africa, the rinds are sliced and dried. The resulting brown circlets are sweet, and are eaten cooked. The fresh rinds are also often carved as table decorations—typically, the fruits are cut in half, scooped out,

and then heaped with colorful mixtures of edible treats. Pickled watermelon rind is widely eaten in parts of the southern United States. In much of Asia, watermelon chunks are similarly preserved in brine.

Seeds In parts of West Africa, particularly Senegal, seeds are used in food preparation. Usually after roasting or frying (which imparts a nutty flavor), the small dried kernels are cracked between the fingers to extract the oily white seeds. These are ground into a smooth meal that supplements cereal flours (such as for use in couscous), or mixed as a pasty thickener to form soup broth. Roasted, pounded seeds are also wrapped in green leaf, steamed, fried, and marketed as a snack with red pepper sauce. In Nigeria, seeds are squeezed into melon-seed balls that are fried (robo) or steamed (monu).

Vegetable Oil The oil in the seeds is yellowish, edible, and semi-drying. It is suitable for cooking and salad oil. It is extracted locally in West Africa by boiling a mass of pounded seeds and decanting the oil off the top, or by applying pressure to seeds that have been pounded and steamed. In Israel, where seedless fruits are sold in the markets, the fruits of the male pollen donors are collected and their seed extracted for snacks.

Leaves The young leaves and shoots are widely cooked as vegetables, added to soups, or used as a relish. In East and southern Asia they are often a component of salads.

Flowers These are edible and said to be delicious battered and deep-dried (like pumpkin flowers).

Animal Feed Wild watermelons are often the only source of moisture for animals, both wild and domestic. Moreover, the seedcake left after the oil has been extracted can be used as a livestock feed.

NUTRITION

At first sight, watermelon fruits are hardly nutritious; no one eats them for their health.[8] The edible portion, which typically constitutes about 60 percent in the modern types, is about 90 percent water and 8 percent carbohydrate, essentially sugar.

Watermelon, on a dry-weight basis, could be considered a significant source of provitamin A (more than 300 RE per 100 g for some red types) and vitamin C (nearly 100 mg per 100 g). However, since watermelon is mostly water, not everyone will sit down and eat their quota ... though many

[8] "Lets face it, it is not broccoli!" a contributor wrote. "It is nothing more than a sack of water with a high sugar content that is a gift from the gods. No one really cares what vitamins or minerals it has. They appreciate it for what it is, and are thankful."

people do. Nonetheless, a "normal" serving provides a good nutritional boost, up to a quarter of daily needs. Red types may have more provitamin A activity than yellow or white forms, as the red color comes from the pigment lycopene, a carotenoid of special interest these days as a potent antioxidant. At about 80-100 mg lycopene per 100 g dry weight, the red flesh can contain half-again the lycopene of fresh tomatoes. As for minerals, watermelon is a fair source of potassium (about 120 mg per 100g), but not as good as banana (about 400 mg) or tomato (about 220 mg). It is low in sodium, high in fiber.

Unlike the fruit, the seeds seem very nutritious even at first sight. They contain 20-50 percent or more oil and 20-40 percent protein as well as good quantities of minerals and B vitamins. More detail is given in the Egusi chapter of the companion volume on African vegetables.

HORTICULTURE

The watermelon's cultivation is too well known to require great detail here. The plant is grown from seed. On dry sites, planting is done as the rains begin; on moist sites the crop is sown as the rains end. For good germination, soil temperatures must be at least 20°C. Seeds, in groups of 1-3, are sown 2-4 cm deep in trenches, on mounds, or in widely spaced planting holes. Later, the seedlings are thinned to one per station. Alternatively, seedlings may be raised in containers and transplanted when 10-14 cm high. Ideally, the fruits should be matured on a pad of grass or straw for protection against soil pests and blemishing. Pollination is by insects, notably honeybees, though other bees may be more effective.

The viney crop is often inserted into a rotation following the harvest of a staple such as maize, millet, or sorghum; in many Asian and African countries, it is also commonly grown as an intercrop, directly with the main crop. In Africa, some watermelons are never planted at all; after a field is cultivated, some are left to sow themselves the following season. However, the selected types used for cooking or eating fresh are always planted, also usually as an intercrop. The wild strains used as emergency food and for their seeds are left to sow themselves on the edges of cultivated fields and in unfenced areas.

Pests of the growing plants include melon fly (*Daucus* spp.)—the most serious pest in Africa, but some wild strains apparently remain unaffected. Root knot nematodes are also problematic.

Major diseases include bacterial fruit blotch, damping off, anthracnose, powdery and downy mildew, *Fusarium* wilt, gummy stem blight, and various viruses (e.g., watermelon mosaic virus). The viruses are transmitted by aphids and cucumber beetles, which must be controlled. A number of watermelon varieties show resistance to *Fusarium* wilt and these should be employed where soils are infected with this fungus. As in tomato, calcium deficiency can result in a disorder called "blossom-end-rot."

HARVESTING AND HANDLING

Yields are usually extremely high—at least when measured on the basis of wet weight. Each plant of the cultivated types generally produces 5-10 fruits—some of which can be very large. Production ranges from 5,000 to 7,500 fruit per hectare for standard varieties and commercial cultivation methods. This usually equals about 37 to 75 tons per hectare. With the adoption of newer production practices, yields of 120 to 175 tons per hectare are achieved using plastic mulch, row covers, drip irrigation, and hybrids.[9]

Watermelons reach maturity approximately 45 days after blooming, although the timing is highly dependent upon cultivar. They typically are harvested when the tendril nearest the melon is wilting and the "ground spot" on the bottom of the fruits turns from white to yellow. They are hand harvested and should be cut cleanly from the vine to avoid stem damage and prevent stem-end rot.

Because of their minimal starch content, watermelon ripens very little after harvesting. Optimum storage temperatures are reported to be 7-10°C.[10] Below that, they are subject to chilling injury and loss of quality. The fruits are generally consumed within 2 to 3 weeks after harvest, primarily because of the gradual loss of crispness. Quality is determined largely by sugar content, color, and texture, all of which depend on maturity, cultivar, and handling methods. Commercial melons for distant markets are usually harvested when slightly less than fully mature.

These details all of course relate to watermelon cultivated for its sweet flesh. No figures are available on the yields or handling of the wild plants, but in Botswana it has been noted that they produce around 8 fruits per plant. Wild strains are harvested after other crops, and long after the vines have died. Some traditional types will store well for several months and still be edible for a year, and sometimes longer.

NEXT STEPS

In advancing the watermelon to new heights, there is an excellent role for African leadership. As the primary center of genetic diversity, Africa could become the seedbed for change. Many opportunities for improving the strains remain. Two factors are favorable: 1) the cultivars are very heterozygous; 2) inbreeding does not seem to reduce vigor. For the adventurous African plant breeder looking for a challenge, the search for unusual watermelons offers opportunities for satisfaction, perhaps profit, maybe the chance to open up new markets, and possibly enhancing the security of many people. Even individual growers could set up test plots,

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[9] About half of China's crop is cultivated using plastic film covering the ground. This is said to increase yields 50-200 percent, raise sugar content 0.7-1.5 percent, and reduce the maturing period 10-15 days.

[10] Nonnecke, I.L. 1989. *Vegetable Production*. Van Nostrand Reinhold, New York.

Small watermelons–often called "palm" melons because they fit into the palm of the hand–are becoming increasingly popular in the United States, and even smaller ones are available in Asia—in China, Taiwan, and Japan for instance. At 2-3 kg, however, most are still too large (or have other shortcomings such as texture, flavor, seediness, or durability) for them to reach their full market potential as "single-use" fruits. Africa's wild watermelons can be as small as 2 cm in diameter, and likely contain "downsizing" genes that innovative horticulturists could employ to create handy fruits of less than 1 kg. (George Boyhan)

challenge types from around the world to local diseases and harshness of all kinds, indeed, become the global go-to experts for the future of the crop. Examples follow.

Upgrading Watermelon In addition to direct use, there is the possibility of employing genes from Africa to influence the watermelons used around the world, so now seems a good time to pay more attention to the cultivated watermelon. In cost-per-kilo it is usually the most economical fruit, and it is already changing its spots in industrialized nations, where new varieties with potential to help farmers and consumers in less fortunate regions have also been developed. Further, much has been learned in recent years about the genetics of drought tolerance, disease resistance, and other desirable traits, making "new" genes even more valuable. Today, watermelons are taking on whole new looks, as yellow, seedless, and small-sized types grab increasing market share. Public demand for greater variety has led to more intensive breeding efforts, which in turn greatly increase the possibilities that totally unexpected qualities will manifest themselves to the alert breeder.

Food Security In particular, watermelon can become a more productive and more reliable source of both sustenance and water for the people, livestock, and wildlife eking out life under some of the world's most tenuous circumstances. While improved types can help, in appropriate drought-stressed parts of Africa the wild watermelon areas might also be protected from commercial over-exploitation; they are primary means of survival for desert peoples and wildlife during periods of drought.

Genetic improvement Genetic improvement might include such things as the following:

- Plants with vigor, earliness, high yield, exceptional sugar content, and resistance to disease (*Fusarium* wilt or anthracnose, for instance);
- Fruits whose rinds are thin and yet strong enough to withstand damage during handling and storage;
- Fruits whose flesh is crisp, sweet, and free from stringiness;
- Fruits with few or no seeds; and
- Plants producing high yields of seed and seed oil.

An intriguing possibility is hybridization with other species in the genus, especially *Citrullus ecirrhosus* and *C. colocynthis* (see below). Both contain useful genes, especially for drought tolerance and perhaps for disease resistance as well. Watermelon landraces in Niger already appear to contain genes from the latter, presumably from natural hybridization.

Nutrition Although food value is not a paramount virtue of this crop, nutritional analyses should nonetheless be done on each of the cultivars. The carotene and lycopene contents should especially be compared. This would help to encourage higher production of the more nutritious types and a search for even better ones.

Genetic diversity There's no telling what strange types might be found from the wilds of the Kalahari as well as the Sahel. The future is wide open to discovery. These are also excellent opportunities for sharing the benefits of such biodiversity with the communities living in these areas.

Vegetable Types Many Africans eat watermelon seeds as an important source of protein and vegetable fat, so large-seeded varieties are also useful. The seeds of these special types are promising sources of oil and protein, nutrients that are especially valuable in drought situations when watermelons are often the only crops left growing. Investigations to enhance the "vegetable" characteristics of the flesh might also seem in order.

SPECIES INFORMATION

Botanical Name *Citrullus lanatus* (Thunb.) Matsumara & Nakai

Family Cucurbitaceae

Synonyms *Citrullus vulgaris* Schrad. ex Eckl. & Zeyh.; *Colocynthis citrullus* (L.) O. Ktze.

Common Names

Afrikaans: wartlemoen, waatlemoen
Botswana: marotse/makatane (an orange-fleshed type for cooking only), mmamonwaane (a white-fleshed type eaten raw), mokgatse (a yellow/white type cultivated for stock feed), tsamma (wild type)
English: watermelon, edible-seed melon
Ethiopia: hab-hab (Am/O)
French: pasteque
German: Wassermelone
Kenya: mtikiti, masindi
Malawi: chimwela/o, mavwende (Ch), litichiti (Y), chimwamaji (Tu)
Mali: zéré, zere (bambar)
Mauritius: melon d'eau
Namibia: oontanga (Oshiwambo)
Nigeria: ibara, bara, egusi ibara
Somalia: Kare (Som)
Russian: arbuz
Sudan: khujar, bateech, buttiku (Arabic)
Tanzania: mtikiti, maji/mkubwa, masindi
Zambia: chimwanyanza, chivwembe, ntanga (Ny), ntanga, chitatakunda (B)
Zimbabwe: muvembe, mugibe, munwisi, munwiwa, muvise/i (C), inkhabe (Nd), makavatya (H), budzi (W)

Description

The plant is an annual climbing or trailing herb with long runners. Some have a fetid musky odor. Its pinnately lobed leaves distinguish it from melon and cucumber (*Cucumis*) and pumpkin and squash (*Cucurbita*). Watermelon is monoecious, with the pale yellow male (staminate) flowers blooming first. Insects, especially bees, transfer the pollen from male flowers to female flowers, making fruit set possible.

The vines carry anything from 2 to 15 fruits weighing up to 50 kg or more. Seeds may be white, green, yellow, brown, red, or black in color. Wild watermelons look like conventional watermelons in size and shape,

except for the wild tsama, which is small and round (average diameter 15 cm or less), with flesh varying from orange to white.

Distribution

This native of southern tropical Africa is now widely spread throughout the tropics, subtropics, and warm-temperate zones.

Horticultural Varieties

There are hundreds of varieties, and most countries have local cultivars; numerous websites list their merits.

Environmental Requirements

Watermelons are a warm-temperature crop requiring a relatively long, hot growing season (usually about 4 months of frost-free weather). Although drought-tolerant, they require a steady supply of water for best fruit production. A committed grower needs the right kind of soil, long warm summers, and not too much rainfall.

Rainfall The plant may require only a small amount of rainfall (250-500 mm), since the root system can usually exploit deep soil moisture. Excessive rainfall and relative humidity reduce flowering, and encourage development of leaf diseases. Waterlogging kills the plants.

Altitude Watermelons grow well up to 1,000 m in the subtropics, and may reach 1,500 m above sea level at tropical latitudes.

Low Temperature For growing watermelon the optimum temperature range is 23-27°C. Growth stops below about 18°C and the plants are very susceptible to frost. This limits their production in regions with cool summers or sharp nights. For germination of seeds, the minimum soil temperature at 5 cm depth is 15°C.

High Temperature Wild melons of southern African deserts grow where the temperature is often 36°C. While temperatures over 30°C during blooming may reduce fertilization in many types, most plants tolerate higher temperatures for short periods. Temperatures of 40°C and above have been measured in Botswana, though extremes can also damage ripening fruit.

Soil Watermelons grow on any type of soil, but do best on well-drained, sandy loams, with good moisture-retaining capacity and high organic matter. They grow successfully on soil of low fertility. Soil depth should be at least 10 cm. They tolerate both acidity (pH as low as 5.0) and alkalinity (up to 8.0); the optimum range, however, is pH 5.5-7.0.

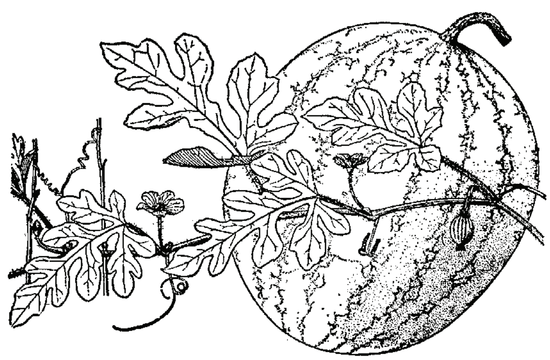
Related Species

Watermelon belongs to the family of climbing plants that includes gourds, melons, gherkins, cucumbers, and loofahs. The genus *Citrullus* contains three or four species, native to tropical and subtropical Africa, one (*C. colocynthus*) being also native to South Asia and perhaps Australia.

In Namibia, the word tsama (or tsamma) is used not only for the wild watermelon, but also for *Citrullus ecirrhosus* Cogn., or “bitter apple.” This desert perennial lives where rainfall is almost nonexistent, and it has a tremendous capacity to survive drought. Not only does it employ water from the very occasional rainfall, it has a remarkable ability to reach moisture deep underground and possibly to employ morning fogs as a moisture source. Its fruit is inedible unless reboiled many times, but its genes might be useful in helping the watermelon crop survive drought even better. Though cucurbitacins are in the seed (as well as the fruit), the oil can be decanted from crushed seed to remove these bitter substances in times of dearth. It has been successfully crossed with watermelon, opening the possibility for new genetic advances in one of the world’s special crops.

Another “bitter apple,” native from Africa to India, is *Citrullus colocynthus* (L.) Schrad., also called the “vine of Sodom.” Growing at the edge of rainfall, this perennial has edible, even nutritious, seeds, which are often found in archeological digs. However, the unripe flesh contains an exceptionally bitter alkaloid and resin that combined creates one the most violent purgatives known. For this reason, it has been studied in some detail, but its potential contributions to watermelon–in the future and perhaps even in the past–still await the curious to discover.

Both species have great bitterness, something they share with the ancestor of watermelon. The fact that our ancestors worked with such a raw ingredient to create today’s watermelon, the epitome of sweet summer juiciness, bodes well for the future of many such “unpromising” fruits.



LOST CROPS of AFRICA

volume III part 2
Wild Fruits

INTRODUCTION

Most of Africa's edible native fruits are wild. One compilation lists over 1000 different species from 85 botanical families and even that assessment is probably incomplete.[1] Among all those fruit-bearing plants, many of the individual specimens growing within Africa are sheltered and protected, some are even carefully tended, but few have been selected to bring out their best qualities, let alone deliberately cultivated or maintained through generations. They remain untamed.

Despite the vastness of the resource, wild fruits are rarely included in development activities. At most, they get only sketchy horticultural attention; seldom, if ever, are any grown in organized plantings. Indeed, apart from listings in the tomes of taxonomy, Africa's wild-fruit wealth is essentially unknown to science.

For all the lack of research, wild fruits still play a crucial role in Africa's rural areas, yielding the very young a key link that helps a fragile nutritional chain from parting. This is because, unlike most grains and vegetables, fruits generally do not need cooking and—requiring no adult intervention and being tasty to boot—they are sought out especially by children. This is important because children are malnutrition's greatest victims.

In this sense, these wild fruits are Africa's most nutritionally important resource, critical to everyone during their founding years. Gathering fruit has been a routine of growing up throughout the millennia of our existence. In rural areas everywhere on earth, wild fruits contribute to nutrition and health during the most vulnerable period of human life. During the crucial years when young bodies and brains are developing, wild fruits can provide the vital nutrition.

In addition, scavenging for fruits is exceptionally important to youngsters in the many cultures that prepare meals fewer than three times a day. Often, adults have neither time nor means to prepare supplementary snacks, so youngsters, whose small stomachs can barely hold enough to sustain their daily needs, rely on the fruits of the field, woodland, wetlands, forest, savanna, or hillside to fill the voids and carry them through. The amounts consumed may rarely have been large. But even a few small fruits that are nutritionally dense can deliver big benefits when the rest of the diet is deficient in vitamins and minerals, which is especially the case when it is overly dependent on starchy staples.

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[1] See Martin, F.W., C.W. Campbell, and R.M. Ruberté. 1987. *Perennial Edible Fruits of the Tropics*. Handbook No. 642. U.S. Department of Agriculture.

Although nowadays such childhood experiences may seem old-fashioned in cities worldwide, they still pertain in vast rural areas of Africa. A surprising number of wild fruits contribute to countryside nutrition, and also to commerce, as seen in local markets. In Swaziland, for example, surveys found that people eat products from more than 220 species of wild plants; about half fruits.[2] A similar audit in Cameroon identified over 300 trees whose fruits or seeds were eaten, including 200 forest species.[3] In Uganda 105 wild fruits are recorded as still being used.[4] Similar inventories are documented in enough places to make this a fair reflection of the norm.

Today, however, these wild resources are getting harder to find. Rummaging through the bush around a village may still be important but, taken all round, wild fruits are a vanishing breed. And no one is doing much to counter the trend because today's overwhelming emphasis is on domesticated crops, especially staples. That choice is certainly understandable, but more thought needs to be given to fostering wild fruits and restoring their productive contributions to Africa.

This added priority is needed because times are rapidly changing. In the past, rural communities living near wild growth didn't need to consider propagating these trees; nature satisfied their needs. Yet with dwindling tree cover, the useful species must be brought in from the wild or risk being lost entirely. Arguably, wild fruits comprise Africa's most vulnerable food resource sector and, because of the pre-existing condition of scientific neglect, their shaky status will only worsen unless there is incisive intervention. Nudging nature even a little is often enough to tilt the balance in favor of a wild fruit establishing or persisting in lieu of scrub; research and its application can work wonders. This is why we devote the second half of this volume to the topic.

What could be done to rescue such historically vital contributors from neglect and possible extinction? First and foremost, wild fruits can be rescued from the widespread belief that they represent backwardness—that in a modern society, foraging is demeaning. Certainly, wild fruits are typically smaller, the pits larger, and the flavor more varied than in comparable cultivated fruits, but that does not mean they are unworthy. Publicity and education are needed to quash the common impression that wayside fruits are "simple," "substandard," "unfashionable" fare.

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[2] When the survey was made (at the beginning of the agricultural season, a time when food stores often are low) more than 50 species were contributing to the local diet *each* day. Antonsson-Ogle, B. 1990. Dietary use of wild plant resources in rural Switzerland. Pp. 895-910 in *Proceedings of the Twelfth Plenary Meeting of AETFAT, Symposium VIII.* Mitt. Inst. Allg. Bot., Hamburg.

[3] Information from J. Vivien and J.J. Faure of Cameroon's Centre Universitaire de Dschang, which has established a native fruit tree arboretum containing 60 species.

[4] Goode, P.M. 1989. *Edible Plants of Uganda: The Value of Wild and Cultivated Plants as Food.* Food and Nutrition Paper 42/1, FAO, Rome.

Wild fruits also need rescuing from the notion that they are solely for the young or that it is degrading to eat such things. Such attitudes ignore the nutritious resources that are on hand. Ironically, this is an era in which nations almost everywhere are exhorting their citizenry to eat more fruits—the wilder the better it seems. In market economies especially, consumers can have a large influence on what is being studied and sold. Everyday, Africans can also call for emphasis on their popular preferences, many of which are not the fruits of urban life and mass cultivation. That, in turn, may bring support and attention to fruits such as those described here.

Technical interest and professional support for wild fruits are also crucial. Currently, textbooks, the international literature, and foreign advisors rarely mention, let alone promote, resources with names as strange as aizen, icacina, or imbe. As noted, nearly all activities in African agriculture emphasize the top international crops whose qualities are beyond question. While the focus on staples and markets and exports is right and proper, quality remains as desirable in eating as in other spheres of human enterprise. And fruits contribute most to the *quality* of eating. And of course, their nutrients—notably vitamins—act catalytically in tiny amounts to help the body employ the bulky staple foods most efficiently and effectively. From development banks and funding agencies to the peer-reviewers who judge research proposals, decision-makers can open their eyes to the African bounty that nourished people long before wheat, rice, soybean, maize, mango, or avocado were seen by human eyes.

The importance of the wild-fruit resource can be incorporated not only into public perceptions but also into landuse. The disappearance of wild fruits is partly due to the destruction of their habitat. Under the pressure of population or politics or profit, the groves of good nutrition near villages and towns get cut or burned or drained or contaminated by waste. To this extent, the deficiency in childhood nutrition is homegrown, and the value lost is as much to people as to the environment.

In short, the underexploited fruits—the truly "lost" fruits—described in the following chapters can contribute much more to Africa than they do today. Indeed, as the rest of this section indicates, many might well come to prominence. First, they taste good and add variety for the palate. A key advantage is, of course, adaptability to Africa's climates and conditions. Another advantage is that the plants are already spread across the African continent and are well known to many users, especially those among the destitute, who employ them to add culinary variety, flavor, nutrients, and sometimes even substantial energy to diets derived from bland staples. Some are even used as sources of water.[5]

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[5] It is little-recognized that wild fruits quench thirst safely. Filled with pure water, they contributed to public health long before the concept of Public Health was recognized. Wild watermelons and several other African fruits are even today more appreciated for moisture than for nourishment.

The following 14 chapters highlight a small selection of wild fruits that appear capable of contributing broadly to Africa's future well-being. Their individual potentials are also summarized immediately below. As with the species treated earlier, these have been chosen from the recommendations of hundreds of researchers who participated in the first phase of this multi-part investigation of Africa's promising indigenous food plants. It should be understood that these 14 are *representative* of the wealth to be found among Africa's untamed fruit resources. They are not the only examples, nor perhaps even the best for any given location. Other species should thus not be judged inferior just because they received no mention in these pages. All in all, the fruits described below offer just a sampling of available and practical tools for working on chronic problems such as malnutrition, food insecurity, rural decline, and environmental destruction. They should be brought in from the wild.

SUMMARIES OF INDIVIDUAL SPECIES

Following are short summaries of 14 promising wild fruits selected for treatment in the second half of this volume. Following these summaries are targeted discussions of their potential for meeting development challenges in Africa. Table 2 (page 194) summarizes their potential across Africa. This summary information is also found in the detailed chapters dealing with individual crops.

1. Aizen (Mukheit)

The aizen or mukheit (*Boscia senegalensis*, Capparaceae) occurs in a vast swath across the top of sub-Saharan Africa, from Somalia in the east to Mauritania in the west. Usually a scrawny shrub, it occupies some of the hottest and driest locations faced by plant life. Yet aizen not only survives, it also yields an array of useful products—enough indeed to sustain human life almost by itself. In at least a dozen countries, people at times virtually live off aizen's fruits, seeds, roots, and leaves. Although not unpleasant to eat, the fruits are most notable for being available when little else remotely edible is to be found. In addition, the seeds extracted from within those fruits are cooked and dried, and become such common dietary items that they have been described as desert dwellers' staples.
Climate Arid.

2. Chocolate Berries

Several of the nearly 70 *Vitex* species (Labiatae) found scattered across tropical Africa produce fruits of local importance. These small and rugged trees are quintessential wild food resources. In season, they become bespangled by an abundance of blackish fruits, which passersby eagerly gather up. The reason? Although the uninitiated may disdain the pungent scent and stained lips, almost everyone loves the "chocolate" flavor.
Climate Tropical.

3. Custard Apples

The plant-family botanists call Annonaceae produces fruits crammed with a sweet pulp with a custard-like texture. These tropical delights are sold the world around under names such as "custard apple," "cherimoya," or "sops" of various vintage. They are already among the most beloved fruits in tropical Asia and America, but so far the African members have been neglected and are poorly understood even within their natural habitats. What might be called "the lost sops" deserve further development, not to mention protection from disappearance. One, the African custard apple, has been called "the best indigenous fruit in most parts of tropical Africa." Another,

the junglesop, produces probably the family's biggest fruits—as long as a forearm and as thick as a thigh. A third—perhaps the strangest of all—"hangs like a bunch of sausages," each fruit a separate bright-scarlet link.

Climate Tropical.

4. Ebony

The jet-black, rock-hard heartwood known as ebony is perhaps the smoothest, shiniest, and most beautiful of all the woods; renowned worldwide for expensive carvings, it is regarded as almost a precious material, and can sell by the gram. But *Diospyros*, the name of these trees' genus, actually means "fruit of the gods," and outside the tropics ebony species are most renowned for the persimmon. In their domicile in the wild, African members of the Family Ebenaceae also produce widely enjoyed fruits. And they could be much more widely enjoyed. The fruits have advantages: They are suitably sized for marketing on a large scale, attractive to look at, and appealingly succulent and sweet. They are, however, very soft and delicate. This fragility is at present the biggest—perhaps the only—barrier to ebony fruits becoming a valuable, everyday, Africa-wide food.

Climate Mostly tropical.

5. Gingerbread Plums

Within virtually the whole of sub-Saharan Africa—the vast stretch of territory between Senegal and Madagascar—there exist a number of interrelated wild fruits (*Parinari* and kindred genera of the Family Chrysobalanaceae) with agreeable strawberry-like flavors. These so-called gingerbread plums can have a texture firm enough to crunch like a crisp apple. Usually red or yellow in color, these plum-sized delicacies lack the sourness typical of wild fruits (and of true plums, for that matter). Millions of aficionados, notably children, love their crunchy sugariness, and consume them in quantity.

Climate Moist tropical and subtropical.

6. Gumvines

Some of the roughly 17 *Landolphia* species (Family Apocynaceae), occurring mainly in West and Central Africa, bear masses of fruits that make tasty morsels. These "gumvine fruits" or "rubber fruits" look somewhat like apricots, with tough skins that are red, yellow, or orange in color. The plants themselves are common and are obviously at home in the African environment. They are forest lianas and sprawly shrubs nowadays admired for their jasmine-scented flowers as much as for their plentiful fruits or the latex-filled stems that once provided Europe and other parts of the world with much of their rubber.

Climate Tropical savannas and forests.

7. Icacina

Icacina (*Icacina oliviformis*, Icacinaceae) is a small, drought-resistant shrub forming dense stands in the West African and Central African woodlands and plains. Although the species is truly wild, several million people rely at various seasons upon its separate products: fruits, seeds, and tuberous roots. The fruits are usually consumed fresh. Bright red and plum-like, they have a sweet and pleasant flavor. The plants grow so densely and yield so exuberantly that during the season a family can reportedly collect hundreds of kilos of fruits a day, even from untended wild stands. The small, round seeds from the center of the fruits are also edible. And the huge edible roots are so much like a much better known staple that their common name in English is "false yam."

Climate Moist and seasonally dry tropics.

8. Imbe

Food and travel writers commonly elevate Asia's mangosteen into the lofty level of "world's most delicious fruit." However, the plant producing it happens to be only one of 400 *Garcinia* species found across Asia and Africa. Africa's best-known member is the imbe (*Garcinia livingstonei*, Guttiferae), a crooked tree whose soft and colorful fruits brighten up markets from Senegal to South Africa. This small, orange-colored delight provides a juicy pulp that has a pleasantly sweet-to-acid flavor. East Africans have dubbed it "King of Fruits." Even those specimens that are unusually sour prove notably appealing on a hot afternoon.

Climate Moist tropics and wooded plains.

9. Medlars

In East, Central, and southern Africa at least eight species of *Vangueria* (Family Rubiaceae) commonly grow with surprising vigor in dry, eroded, infertile, leached, or otherwise challenging sites. These trees closely resemble one another in both appearance and a propensity to bear lots of fruits. For want of any popular name in English, they are called wild medlars or African medlars. The fruits dry easily (even drying out before they are picked), after which they take on the aroma and flavor of dried apples. Reconstituted with water and a little sugar, they substitute for applesauce as well as being used as fillings in puddings and many more culinary products.

Climate Woodlands, scrub, valleys, stony hillocks, or sandy dunes.

10. Monkey Oranges

Three monkey oranges (*Strychnos cocculoides*, *S. spinosa,* and *S. pungens*, Strychnaceae) produce fruits that are large, flavorful, easy to

handle, and often desperately difficult to find due to overwhelming demand. Farmers appreciate the trees so much that when clearing land they spare the ax—even when that will hinder their subsequent field operations. Of all Africa's wild fruit trees, these are the most "conventional" in appearance and usage. They are similar in size and shape to apple, pear, and orange trees. Given horticultural attention, monkey oranges probably can be raised with equal facility. Already, they bear their fruits in abundance.

Climate Savannas and dry woodlands.

11. Star Apples

In many tropical American countries, especially in the Caribbean, the star apple (*Chrysophyllum cainito*) is a common dooryard tree whose apple-sized delights provide a sweet flesh with small seeds arranged in a star pattern. What is not well known is that the area below the Sahara contains more than a dozen related species. These attractive trees of the genus *Chrysophyllum* and *Bequaertiodendron* (Family Sapotaceae) create their own edible counterparts whose smooth green, purple, apricot, yellow, or copper-colored skin encloses a white, sweet, tasty pulp. This pulp is arranged in segments and, when cut transversely, typically displays the star-shaped seed arrangement that constitutes the family crest.

Climate Lowland tropics and subtropics.

12. Sugarplums

Africa is home to more than 30 species of wild fruit trees belonging to the genus *Uapaca* (Phyllanthaceae; also placed in Euphorbiaceae or Uapacaceae). Several produce flavorful, attractive fruits that engender enthusiasm wherever they occur. These delights add a sweet yet tangy zest to traditional foods from porridges to desserts. Fully ripe, these are plum-sized, yellow-brown in color, juicy, and honeylike in taste.

Climate Seasonally dry wooded parkland.

13. Sweet Detar

Throughout much of tropical Africa the detar tree (*Detarium senegalense*, Leguminosae) is common and its round brown pods well known. At first sight these fruits look like apricots, but physically they are more like tamarinds, with a crisp shell enclosing a rather flaky greenish pulp that makes good eating. As with tamarinds (see Part 1), sweet detars are especially enjoyed in West Africa. Most are eaten fresh, but some are dried in the sun and sold in the markets like dates. The hard shell and dry pulp give them an exceptional shelf life and the sweet-and-sour flavor appeals to most every palate.

Climate Woody savannas and parkland.

14. Tree Grapes

About 40 different trees of the genus *Lannea* (Family Anacardiaceae) are to be found in the tropics of Asia and Africa. The species in Asia have received horticultural attention, but the 20 or so that are native to locations from Madagascar to The Gambia remain unmoved by modernity. Yet at least a dozen of these wild fruits could be valuable future food resources. Although belonging to the same plant family as mango, cashew, and pistachio, their fruits are more like grapes in form. They come in pendulous bunches and are reddish, purple, or black in color with a whitish bloom on the skin. Although some have a resinous taste, many have a pleasant flavor described as truly "grape-like."

Climate Tropical forests to tropical savannas.

TABLE 2: POTENTIAL ROLES FOR SELECTED WILD AFRICAN FRUITS

*** = ***Outstanding;*** ** = ***Notable;*** * = ***Average***	Overall	Nutrition	Food Security	Rural Development	Sustainable Landcare	PRIMARY OCCURRENCE			
						West Africa	Central Africa	East Africa	Southern Africa
Aizen (Mukheit)	***	**	***	**	***	√		√	
Chocolate Berries	***	**	***	***	***	√	√	√	√
Custard Apples	**	**	*	**	*	√	√	√	√
Ebony	***	**	***	***	***	√	√	√	√
Gingerbread Plums	***	**	*	***	***	√	√	√	√
Gumvines	**	**	*	**	**	√	√		
Icacina	**	**	***	**	**	√	√		
Imbe	**	**	*	***	**	√	√	√	√
Medlars	***	**	***	***	***		√	√	√
Monkey Oranges	**	?	***	***	***	√	√	√	√
Star Apples	**	*	*	**	***	√	√	√	√
Sugarplums	***	***	***	***	***	√	√	√	√
Sweet Detar	***	***	***	**	***	√			
Tree Grapes	**	**	**	***	**	√	√	√	√

NB: The underlying justifications for these broad rankings are discussed in the following sections on Nutrition, Food Security, Rural Development, and Sustainable Landcare; greater detail is provided in the separate chapters on individual crops.

POTENTIAL ROLES FOR SELECTED WILD AFRICAN FRUITS

To give some idea of their potential to help overcome the great central issues of African humanitarian and economic development we now summarize the above mentioned wild fruits' likely relevance to four of Africa's biggest needs for survival and social stability: nutrition, food security, rural prosperity, and general landcare.

OVERCOMING MALNUTRITION

Wild fruits can contribute to overcoming malnutrition because the plants survive where their more pampered kin perish and thus produce nothing whatever. Additionally, because wild plants are necessarily self-sufficient, they promote well-being for future generations as well as for the present.

It is noteworthy that harsh and difficult locations contribute disproportionately to malnutrition mortality. So, even with their limitations, wild fruits often offer a good at-home solution. And, with better knowledge and more attention, wild fruits can contribute much more.

On the other hand, these species are essentially unknown to medical doctors, nutritionists, bio- and analytical chemists, agronomists, horticulturists, or even the technical literature. Only a few have been analyzed in detail for nutritional components, and whether those results are representative is uncertain. Therefore considerable ambiguity over their true relative worth, let alone their future, is to be expected.

Below is a summary of the merits, *specifically in terms of fighting malnutrition*, of each of the wild fruits highlighted in the second section of this book.

Aizen (Mukheit)

Aizen's nutritional content is poorly known but people existing in the extreme climates where the plant grows can rarely expect foods of high nutrition. They *can*, however, get aizen…and giving them easier access to more of it could prove a key for reducing mortality in the locations that contribute more than most to the suffering caused by extreme malnutrition. The pulp reportedly contains good calcium, phosphorus, iron, and some B vitamins. It is said, however, that its main value is in supplying vitamins A and C. It also provides a little protein. Inside are greenish seeds that resemble peas in appearance and usage. Nutritionally speaking, these are perhaps the better instrument for inducing healthier living. They have as much starch and soluble carbohydrate as the local grains (sorghum and millet). Their protein content is high (relative to cereals) and it is of at least moderate nutritional quality. The seeds apparently are also rich in zinc, a mineral considered important for maintaining and recovering well-being.

Chocolate Berries

Little is presently known of the chocolate berries' nutritional contributions. In Sierra Leone they are claimed to cure a condition—associated with sores at the corners of mouth and eyes—that is described as a nutritional deficiency caused by lack of vitamins B and A. As tools for malnourished children's self-medication they might prove exceptional, seeing the plants are adaptable, rugged, self-sustaining, high yielding, and within the reach of little fingers.

Custard Apples

These are sweet, flavorful, attractive, and likely to provide nutrients in reasonable quantity. Based on analyses of custard apples from other regions, they should possess moderate amounts of calcium and phosphorus (30-40 mg per 100g), modest amounts of vitamin-A precursors, and reasonable amounts of the B vitamins thiamin, riboflavin, and niacin. Their sweet and custard-like pulp should provide a potent means of delivering nutrients to needy small ones because it appeals so much to the young in years.

Ebony

As far as nutrition is concerned, the pulp of Africa's native persimmons can be expected to be rich in vitamin C, with perhaps 25-50 mg per 100 grams. Interestingly, like apples, common persimmons have more vitamin C in their skin than their flesh. In addition, the skin's bright red color likely reflects the presence of lycopene, the nutritionally valuable carotenoid found in tomatoes.

Gingerbread Plums

Gingerbread plums seem like powerful tools for building better bodies. Their colorful skins, bright yellow flesh, and high sweetness endow special appeal. Millions of Africans adore them. When in season, some peoples treat them almost as a daily staple. And the tough-skinned fruits are easy to handle, resisting bruising and shipping damage. Other than crude proximate analysis, little is known of the food value. Nonetheless, they seem likely to be a good nutritional support, especially for the young and the vulnerable.

Gumvines

Juice of these fruits is regarded as extremely healthful, and probably with good reason, although the nutritionally important ingredients are little-known at present. People often substitute it for lime juice to season rice, maize, and other grains; prepare lemonade-like drinks; make a type of beer; and flavor foods such as fish. Thus, gumvine fruits are probably a good means for delivering nutrients to all levels of society.

Icacina

No one yet fully knows the contributions this species makes to nutritional well-being, but also no one doubts that it is positive. Icacina is renowned as a living grocery store during normal times and an emergency food during hungry times.

Imbe

This fruit would likely make a good tool for the suppression of nutritional deficiencies because it is popular in the diet. The pulp is yellow and watery, and has a pleasing sweet flavor—described as "not unlike a perfect peach." It is eaten raw but is more commonly cooked with porridge and other cereal products. Thus, increasing the production and consumption of imbe could boost the basic nutritional status of all age groups.

Medlars

These tasty morsels deliver more than just pleasure, and they deserve to be part of nutrition-improvement programs. Although much remains to be done to clarify the nutritional content of the different species, it is already clear that these rugged, resilient trees amount to self-sustaining tools for reducing malnutrition. Typically, these fruits are stored in dried form, and then boiled into a thick liquid that is used like gravy to flavor staple foods, notably mealies (maize porridge). They are thus a good way to deliver nutrients to both the unhealthy and the unsuspecting.

Monkey Oranges

We're not certain just how to rate these fruits for combating childhood malnutrition. On the one hand, they are among the most popular native wild fruits. On the other hand, their food value is poorly known, and there is the possibility of adverse effects (especially if consumed to excess). Monkey oranges, however, are believed to be rich in the B vitamins and vitamin C. One species (*Strychnos spinosa*) can reportedly be surprisingly rich in food energy—almost one-third fat and an energy level of almost 500 calories per 100g. Even if only verified in rare "sports," it might become especially valuable against marasmus, mortal malnutrition caused by too few calories.

Star Apples

African star apples remain horticulturally undeveloped and their nutritional qualities are poorly known, though their relatives in the Americas have been compared to orange but with half the vitamin C. Despite scientific neglect, however, they are esteemed in many places and are likely to have nutritional merit of at least a modest nature. As weapons for conquering Africa-wide malnutrition, these seem like long shots. But probably, they are

no less valuable than everyday Western fruits—peaches or plums, say—that by default constitute the yardstick for measuring healthy diets in the best nourished parts of the world.

Sugarplums

Although little is yet known about their ingredients, these fruits are thought to be nutritionally outstanding. The level of vitamin C can be especially high. Indeed, the best known species, mohobohobo, produces fruits whose ripe edible part contains 1.8 mg vitamin C per g—more even than guava. Most are eaten fresh, but some are pounded with water and served as drinks or even as a fragrant fruit wine. In addition, tasty snacks are made from the pulp by adding water, flour, and sometimes egg, flattening the mixture into round cakes, and frying them like doughnuts. These variant products offer delivery systems for adding nutrients to whole societies.

Sweet Detar

Sweet detar is an outstanding source of vitamin C—perhaps among the best of all. In 1988, researchers studying 29 fresh fruits consumed in Senegal discovered its pulp to be the richest in vitamin C. Nothing else came close. In addition, the purple-brown, sweetly scented seeds have edible kernels. Flour made from them is notable for having 12 percent of a protein rich in the botanically rare essential amino acids lysine and tryptophan. The kernels are also crushed to extract their oil for culinary use. Collectively, then, the contributions of vitamins, quality protein, and food energy could make sweet detars powerful preventatives and even possible cures for several types of malnutrition and their associated ailments.

Tree Grapes

These children's favorites are seemingly excellent resources, but so far the nutritional benefits remain unrevealed. Likely, these grapelike delights are good sources of provitamin A, iron, and zinc, and might contribute vitally to child survival. If so, these resilient, self-sustaining, productive wild shrubs could be ideal for achieving long-term nutritional care.

BOOSTING FOOD SECURITY

In rural Africa, many people live near wild fruit-bearing trees and bushes that produce food at times when crops cannot. For this reason alone, these plants should not be neglected any longer. In fact, for the reliable food production necessary to Africa's social security and general stability, such wild fruits hold great promise. Diversified diets offer the best nutritional balance, and diversity can be maintained through the combined exploitation of both domesticated and wild foods. Further, wild plants are necessarily self-sufficient species, which, due to age-old adaptations, need little care. They require, for example, no fertilizer or pesticides (at least for survival). Irrigation is unnecessary and disease problems generally are moderate to minimal. On the other hand, insects and higher-order pests can be a menace. The problem here is not so much the loss of the plant but the loss of the harvest. Fruit flies present a perennial problem that is hardly simple or easy to solve, but which can be minimized. In general, however, wild fruits have minimum management requirements for survival, making them ideal for food security, where their contributions may be episodic but vital.

This is not to say, however, that wild fruits cannot be assisted to produce more or to produce more reliably. Indeed, this is what needs to be done. Raising the productivity of wild fruits will help many people who periodically struggle against starvation—disproportionate numbers of whom live in rural Africa and rely on wild fruits when their lives hang in the balance. Such emergency foods are of course critical in the face of famine, but more often their importance is manifest during that annual recurrence known as the hungry season (*soudure* in French)—an agonizing few weeks or months when the last harvest is eaten and the new one is not yet ready.

Below is a summary of the merits, *specifically in terms of food security*, of each wild fruit highlighted in the remainder of this volume.

Aizen (Mukheit)

A food security gem, this fruit has been a proven lifesaver during famines since ancient days. It preserved many lives, for example, during the 1982-1983 Mali drought as well as during subsequent famine in Ethiopia and Sudan. In both cases there was a large increase in aizen consumption. Livestock and wildlife ignore aizen for most of the year, meaning people have few worries about their trees being devoured by goats or gazelles when they are not looking. Nor will the trees end up being destroyed by the desert. For this multi-layer security, alone, aizen is promising for establishing famine-food reserves. Although seasonal, its fruiting differs from the norm and comes when farm crops are just being planted and things to eat are hard to find. This alone also makes aizen a lifesaver. In the slightly better watered zones, where there are other edible plants to choose from, aizen serves

mainly as a supplement rather than a staple. Even so, it remains a valuable backup for devastating drought emergencies that arise seemingly almost routinely every decade or two. Beyond the fruits, the cooked, dried seeds are also important famine-time fare throughout the Saharo-Sahelian zone.

Chocolate Berries

A great intervention for food security. Villagers rely on these trees for much more than just fruits. They boil and eat young leaves like spinach. They depend on the foliage to keep their livestock from dying during the long and trying months when the grass is gone. With more chocolate berries, life might be less hard and more stable in many places.

Custard Apples

Although this is an excellent time to investigate these unusual fruits, food security will probably never be a major merit in their case. They are soft and perishable. Also, the trees are not exceptionally hardy, rugged or tolerant…at least as has been reported so far.

Ebony

Intriguing potentials. In certain areas ebony forests might be established as long-term food reserves, and help save generations of lives. That would be an excellent way to obtain local cooperation for planting and protecting both ebony trees and the environment. Yet it is not just in famine times that these trees become saviors. Every year people store the dried fruits as a reserve to draw on just before the beginning of the next harvest season, the perilous period when food supplies often run low or run out.

Gingerbread Plums

These wild tree fruits are a nice seasonal resource, fruiting when other foods are also normally abundant, but we are unaware of any specific merit for food security during dearth times.

Gumvines

Not recommended for food security purposes at present. In the wild, gumvines do not fruit annually. Also, some species reportedly take as long as 12 months to mature each crop of fruits.

Icacina

This rugged shrub is even now used as an emergency reserve during times when even millet succumbs. It has been known to survive at least *four years* without rain and yields three fundamentally different types of food—fruits,

seeds, and tubers. All three are life savers. The fruits, for example, ripen as the dry season comes to an end, the very moment when the stores of other foods often run out. The seeds can be dried and stored with little fear of loss from mice, mildew, or weevil. And the fleshy, tuberous false yam can be 80 percent starch and sometimes weigh over 60 kg. More programs dealing in African food security should be dealing in icacina. It seems like the finest of food-security instruments for the regions where it will grow…with icacina around people can always eat.

Imbe

Although this rugged little tree survives in locales where food production is tenuous, the fruits don't seem a candidate for food security programs. The trees seem to bear during periods of normal seasonal abundance, and the fruits do not keep well; the seeds, however, may hold more promise.

Medlars

At least in principal, *Vangueria* seems likely to make outstanding contributions to hunger relief. In eastern, central, and southern Africa, at least eight species grow vigorously in sites with challenging soil conditions. Their rather unusual fruits not only dry out and stay aloft on the tree, they remain edible for months. Given their easy desiccation, they can be sun-dried and stored for up to six months and, once reconstituted with water, taste almost like new. Because of this, African medlars are commonly stashed away for times of scarcity. In conjunction with tree planting and tree conservation, their food security talents are well worth putting on the stage.

Monkey Oranges

Monkey orange trees are certainly respected for their shade and good looks. However, the greatest admiration is engendered by the tasty fruits, which are widely enjoyed and have the amazing capacity to stay edible in tropical heat for months. At least one of these species has been called, "A great and precious resource in times of crop failure." The fruits can be buried several months, and (as long as care is taken to keep the shell whole) they come out of the ground juicy, golden, and perfect for eating. These are important resources for the future and seem likely to prove valuable tools for delivering a more secure life to those without access to money.

Star Apples

For food security projects this probably has limited potential. However, the trees grow rapidly and (after juvenile vulnerabilities) become almost trouble free, resisting among other things pests, diseases, and high winds. As long as they remain unexposed to freezing temperatures, African star apples

continue producing quantities of delicious fruit year after year while burdening labor almost not at all. That makes them at least a contributor to food, or economic, security.

Sugarplums

In some parts of some countries—notably Zimbabwe, Zambia, and Malawi—sugarplums basically underpin existence for part of the year. This is more a matter of choice than charity: people just like eating them so much. However, the trees generally occupy the drier and poorer areas, and seem at home on adverse sites where food production is generally poor and unpredictable. Because of that feature they have traditionally helped millions survive famine. The fruits have exceptionally high levels of vitamin C and definitely deserve consideration in efforts to help free Africa from famine.

Sweet Detar

Sweet detar seems a superb food-security tool. This tree legume is tolerant, adaptable, generally reliable, and relatively insensitive to site, soil, altitude, heat, or humidity. Because of this and because it continues producing fruits for decades on end, sweet detar could be placed in the forefront of many food-security planners' priorities. Silvicultural success could catapult it into a brawny resource that cuts malnutrition and contributes to rural development—all while it grows a great timber.

Tree Grapes

These trees are resilient, drought tolerant, and naturally adapted to harsh sites, including some in which humans sometimes have few food options. They resist the groundfires that are so prevalent and so ruinous in the savannas. The individual species are poorly known to science so no one can now say just what role they might play in food security projects, but on the basis of their resilience and productivity in the untamed wilderness, tree grapes seem likely to prove useful.

FOSTERING RURAL DEVELOPMENT

Although wild fruits have been accorded little horticultural recognition, some clearly promise to help reduce rural poverty and the dissatisfaction that leads to urban migration. This may come through cultivation or improved *in-situ* use in the wild, and it is an endeavor that promises to especially improve the lives of women. In many areas of Africa, gathering wild fruits for sale is considered a female prerogative. It is women who sell the fruits, thereby gaining a small income to supplement the welfare of their families. Any help for the resource will directly help such women and by extension their families. One particularly promising approach is the management and domestication of local fruit trees for the production of "exotic" juices.

Below is a summary of merits, *specifically in terms of rural development*, for each wild fruit highlighted in the remaining chapters of the book.

Aizen (Mukheit)

This little desert shrub seems at first to offer little direct economic benefit. But during the 1984-85 Sudan famine, its seed effectively became the staple of market society, replacing millet and sorghum (which morphed into luxury foods). In addition, the fruits dry down into a sweet delight, not unlike hard candy, that can probably be sold with little difficulty locally and perhaps at a distance. Furthermore, the dried seeds are ground into flour and used like sorghum, millet, or lentils. The processing and selling of fruits, seeds, or flour are possible routes to small-scale prosperity. People who live where aizen grows are among the earth's poorest, but that doesn't mean they are without buying, bargaining, or bartering power.

Chocolate Berries

Rugged, robust, resilient, these woody plants seem capable of contributing to rural development. Certainly a market for the fruits might be developed, but these utilitarian species also offer other potentially saleable products. They yield, for instance, a straight-grained timber resembling teak. They stay green far into the dry season and keep livestock alive (or even in good condition) when death seems the more likely fate. They are favorites for honey producers because bees visit them from afar. Understandably, rural people eagerly plant and tenderly nurture these trees. Thus, although they remain undomesticated, chocolate berries have rural-development potential.

Custard Apples

As noted, tropical America's custard apples (especially cherimoya) are rising in horticultural importance in several parts of the world. Clearly, the African counterparts could now join this culinary wave. Crosses between

different species are also creating hybrids with their own attractive futures. Hybrids between the African species and their transatlantic relatives may well produce brightly colored, larger fruits with few (or perhaps no) seeds. Their genetic qualities, in other words, might bring commercial benefits to two continents at the very least.

Ebony

These persimmon relatives could in the future be widely grown both as village trees and as densely planted stands. Fruit pulp is just one useful product. The seeds of some ebonies are edible. The leaves are used as animal feed. The bark in certain species yields a dark blue dye for coloring cloth as well as a gum used for glue. In the long run, however, the wood would be the greatest financial prize from these forests. Although little is known about their performance under cultivation, their long-term prospects as fruit-and-timber resources could be good. The sale of fruits could support annual maintenance costs and perhaps provide income during the long years in which they are laying down their gold-standard heartwood.

Gingerbread Plums

For purposes of rural development, these fruits seem at least worthy of exploration. They are already used in a variety of ways: some are eaten fresh, some are boiled with cereal, and some are made into colorful drinks, gruels, and syrups. With most of these botanically interrelated fruits the seed kernels are enjoyed like cashews or almonds. Several species are already "semi-cultivated"—farmers clearing land spare good trees and subsequently maintain them for the fruit. This salvage operation has been a first step toward developing a more formal rural resource, now ripe for plucking.

Gumvines

Little importance is nowadays attached to gumvines as potential income sources, but if they can be tamed and turned to use then tropical Africa will have a collection of interesting crops capable of contributing to economic progress. If particularly good specimens are located and produced in quantity, there is even the possibility of exports because the fruits tend to have shelf lives long enough for a sea voyage. Already, they are frequently sold in markets across West Africa. In Mali, Burkina Faso, and neighboring nations you commonly see boys selling them by the cluster along roadsides.

Icacina

This species' potential in poverty reduction is uncertain, but possibly outstanding. Despite being untouched by agronomic science, the plant already contributes to the health and happiness of many. Any improvements,

no matter how modest, could thus have a satisfying impact on rural welfare. People truly enjoy the seeds, which provide a permanent, reliable, and very tasty food with at least modest profit potential to those who produce or gather it. And there are also the fruits and even the tuber in the bargain.

Imbe

Many African peoples already relish these fruits and even in its present unimproved state the species produce abundantly. Moreover, imbe trees integrate into the village scene neatly and form excellent partners in mixed-crop farming. Farmers are almost promised a profit because the general populace places high value on these fruits—indeed, demand is often great enough to go unfilled. The fruits themselves are attractive and of a good size for mass marketing. The trees thrive in adverse sites, including dry, damp, sandy, or rocky locations. They respond vigorously to good culture. Finally, they make excellent village-, farm- or dooryard trees, being tall enough to throw soothing shade over people, paths, and patios.

Medlars

African medlars are promising for commerce, regardless of whether wild or cultivated. All resemble one another in appearance and a propensity to bear masses of fruits. Specimens with as many as 1,800 fruits have been recorded and harvests approaching $100 a tree are claimed. Marketable products include both fresh and dried fruit. Either way, they make food supplements with potentially high nutritional value. They can also be sold in the form of flavorings and beverages. And they provide edible seed kernels.

Monkey Oranges

These trees already provide a profit. Indeed, fruit sell at quite high prices and still demand is seldom met. There is even an extensive local and regional trade and, according to one observer, "[more] are urgently needed to make available fruits for export markets and for processing." Indeed, a much greater commerce in monkey fruits seems eminently possible. A sustainable export trade is not beyond expectation. Zimbabwe has already trucked them to Botswana, and that could be just a beginning. Generally speaking, the three special *Strychnos* fruits are of marketable size and quite stunning to see. They typically store and ship far better than other tropical fruits. Indeed, they can be piled up and stored in the open because their hard, gourd-like shell resists not only pressure but fungi and fruit flies as well.

Star Apples

Today, these species' broader potential is unexplored and their value in organized commercial plantings remains untried. They deserve better. An

important feature is that the fruit becomes available in the dry season, a time when all too often there is not enough to eat or sell. When superior strains become available they seem likely to find ready commercial outlets. However, at present not even the basics of the plant's production, maintenance, or use are well described.

Sugarplums

This is one of the few wild fruits with an organized distribution system. The districts in which *Uapaca kirkiana* grows send the fruits to distant markets. For example, parts of Zimbabwe where mohobohobo trees are abundant truck enormous quantities of the fruits into Harare, where most are sold by street vendors. Already these are quality fruits, but technical support is likely to lift them far above the forest fruits of today in terms of quality and quantity. Indeed, tomorrow's sugarplums could be exceptional resources for reducing rural poverty.

Sweet Detar

For all its utility, this tree remains wild, but it seems like a rural development star in waiting. Although normally consumed out of hand, the fruit is processed into such things as dried fruit "leather" and refreshing drinks. Presently, the species is unknown in intensive plantations or even in extensive village plantings. Rather, it occurs in outlying forests or in farm fields where scattered specimens remain from bygone days when the land was cleared. The trees furnish excellent timber. Often sold as "African mahogany," the heartwood has a fine and regular grain and is eagerly sought for carpentry, joinery, and other premium purposes.

Tree Grapes

Already these are of commercial importance. In certain sections of West Africa they are eagerly consumed and the trees are commonly cultivated in and around villages. At least one tree-grape species produces both prized fresh fruits and long-lasting "raisins." Wherever they occur tree grapes are avidly eaten; some already play a part in commerce. In West Africa, people commonly sell them in the city markets and along rural roadsides, and the grapelike fruits are "very suitable for juices." In addition, the bark yields edible gum, a reddish dye, and a fiber used for cordage and a lot more. The living trees provide poles and floats and fishing nets. Oil from the seed kernel has potential for soap and unguents; in Mali it reputedly strengthens the hair. Because of its shade and manifold bounty, tree grapes are typically protected when the land is cleared for farm fields. As a rural development tool it seems to offer much.

SUSTAINABLE LANDCARE

These days, environmental protection is of vital concern, the subject of solemn conferences and severe treaties. Yet for all the hand-wringing over land degradation, Africa's wild fruits are seldom, if ever, regarded as part of the solution.

This is unfortunate because promoting self-reliant fruits such as those described in these pages offer great prospects for keeping the continental landmass productive. Many of these wild species survive on marginal sites. Indeed, they represent one of the best tools for turning vast areas of what is now eroding, vulnerable wasteland to valuable use. They provide their food bounty without having to be cut down and without disturbing the land. And they give people a personal motivation to protect and preserve not only the trees but also the site and the associated ground cover.

Unlike domesticated plants, the ability of wild fruits' to survive independently of humans makes them especially promising as land-protecting, food-bearing inhabitants of places where human presence is thin or sporadic and almost always vulnerable. As of now, many such threshold locales become abandoned, less to rejuvenation than to wreck. Clearly, wild species are a best choice for extending presence in wild lands. And seeing they provide food seasonally, or even only when calamity strikes, they do a signal service to both the site and the citizenry.

The protection, establishment, and advancement of indigenous fruit-bearing trees can also help underpin sustainable farming practices. In fact, they might well provide shifting-cultivators food and income during the long wearying years while the land refurbishes itself. This "fallow/food-enhancement" system—which both protects the soil and produces something to eat or sell on the side—seems well worth Africa-wide attention.

At the very least, the wild fruits we describe are putative components in sustainable food production. They typically provide more than one edible product (a striking contrast with fruit trees grown in temperate zones) as well as non-edible benefits. For example, in addition to fruits, many are used by herbalists and other traditional healers. As a part of the natural landscape, they also contribute to both the environment and people's inner welfare. They therefore offer benefits both physiological and psychological.

Of course, wild fruits can never replace field crops, but they certainly can complement them in important ways. More than half of southern Africa's land is unsuitable for conventional cultivation. The marginal areas in which farming is attempted remain grossly underproductive due to recurrent drought and chronic soil infertility. In such regions the augmentation of the naturally productive vegetation already in existence can promote nutrition, food security, and rural development. In addition, the plants can be established in hedgerows and along contours to stabilize the slopes, thereby promoting environmental stability while also elevating income and health.

Below is a summary of the merits, *specifically in terms of sustainable landuse*, of each of the wild fruits highlighted in the remainder of the book.

Aizen (Mukheit)

This plant's endurance is remarkable. Shade-temperatures that reach as high as 45°C are far from rare in its habitat. Arid stony slopes, sand dunes, and cracking-clay plains are its bread and butter. This and the fact that livestock and wildlife leave it alone most of the year means people need not, as we have said, worry that their plants will be devastated by the desert or devoured by goats or gazelles. For this double security alone, aizen promises to be a practical way to protect erodible slopes, stabilize dunes, create windbreaks capable of keeping the ground unscoured, demarcate boundaries, and provide shelter for livestock and their owners. Further, aizen provides year-round shade where even slight relief from the sun is a great gift. And it also offers other utilitarian benefits in places where people need help in the struggle of life.

Chocolate Berries

Everyone likes having a chocolate berry tree around, and people already go out, gather the seeds, and deliberately plant their own. These 70 species include some specimens with exceptional promise in agroforestry and rural reforestation. Indeed, those might become standard components in the species mix employed to stabilize eroding slopes and abandoned wastelands across much of the continent. Among other advantages is their longevity. These trees are long-lived; moreover, they're never cut down irresponsibly. Even scraggly wild specimens are protected by societal rules and regulations. Almost everyone—not to mention the environment—benefits from living chocolate-berry trees.

Custard Apples

With their notable sugar content, these fruits appeal as foodstuffs, but the plants fall far short of any ideal for environmental protection. They are certainly capable of surviving without human help, and they add value to wooded wild areas. Though not often stand-alone trees, their shade is also desirable. Thus, people tend to preserve and protect their habitat. But beyond that they are not particularly hardy and seem to do little to save the soil or improve the ambiance in any other exceptional manner.

Ebony

For African agroforestry projects, local *Diospyros* species could be especially valuable. People know and love these trees. As long as superior planting materials are supplied, millions are likely to plant them

spontaneously and protect them from harm throughout a lifetime or two. Even now, volunteer plants are well cared-for. Indeed, African ebonies could become valuable not only for individual plantings but also for bordering streets and highways, for fencelines, for village squares, and for small-scale entrepreneurial endeavors of many kinds.

Gingerbread Plums

Producing vastly more of these tasty fruits under more organized conditions seems eminently feasible. Germinating the seeds is difficult, but most (perhaps all) *Parinari* species are easily reproduced via root suckers. These root cuttings also provide the key to propagating elite specimens. Through them, quality plantings could be quickly and easily established across much of Africa, clustered in villages perhaps, or scattered alongside roads in the valleys and tracks on the hillsides.

Gumvines

Adding vines as valuable as these might raise the economic worth of standing forests—thereby dampening the ardor to burn off the land or cut the trees for lumber. Incorporating gumvines into boundar rows, windbreaks, shelterbelts, and *ex-situ* conservation forest are also possibilities. Species that cling and climb could be a way to increase the utility of many tree plantings that are expected to provide long-term environmental benefits.

Icacina

Icacina forms vast thickets that are about as close to monoculture as can be found in nature. Their denseness protects the soil, which otherwise is often subject to erosion and degradation. This is a feature that might well be turned to environmental advantage.

Imbe

This is an unusual and eye-catching small tree. Its dense, spreading, or conical crown topping a short, often twisted trunk or cluster of trunks makes a striking sight. Its attractive form, together with the year-around foliage and heavily scented flowers, make imbe a landscaper's dream—so much so that it is nowadays planted more for beauty than for food. This certainly opens it up to use for esthetic uses and bigger plantings, but this is probably the extent of its landcare advantages.

Medlars

Across southern Africa, local lore claims that the beneficent *Vangueria infausta* bears fruits heavily just before a big drought. In agroforestry the trees could find a notable niche. Already several *Vangueria* species are used

as hedge plants to demarcate fields and farms. The trees' ultimate continental potential is probably more for back gardens, bare patches of hillside, village greens, or the verges of roads and tracks and rivers.

Monkey Oranges

The trees that yield monkey oranges make excellent additions to gardens, parks, streets, and fencelines—providing not only food but also shade, shelter, and erosion protection. Much more could be made of them in caring for the African land.

Star Apples

Regardless of food production, the various African star-apple species are promising for protecting and improving stressed sites. They could prove useful, for example, in land reclamation, erosion control, and, especially, in reducing wind-erosion. For their ornamental value alone these trees merit attention. People love having one standing beside the house. They might make useful reforestation species too. Fully grown, they top out at 30 m in height and 2 m in girth, and their hard, white wood is world famous for quality and high price.

Sugarplums

Farmers clearing land normally leave every sugarplum standing. These highly respected trees can usefully complement backyard gardens, agroforestry operations, and more. They seem ideal tools for protecting soil as well as for conserving habitat and native biodiversity.

Sweet Detar

Robust and resilient, this large tree is a candidate for reforestation purposes. Although this legume probably does not fix notable amounts of nitrogen, it survives in harsh, infertile sites and tolerates some drought and much heat. All in all, sweet detars seem likely to make good backyard, village, and street trees, providing welcome shade and environmental benefits, not to mention copious food.

Tree Grapes

Although these fruits look like grapes, they are borne on trees, not vines. Even where the fruits go unharvested, the trees are still revered. They coppice well and sprout with vigor, which makes them useful for hedges. While the environmental benefits have yet to be evidenced in practice, they could be so great that *Lannea* species seem promising for vast shelterbelts to settle the soil and make life more livable in their historical heartland across the Sahel.

WILD FRUIT ISSUES

We finish this introduction with passing mention of some strategic issues that seem especially relevant to the further development of Africa's wild fruit biodiversity.

INCREASING WILD FRUIT USAGE

Even where wild fruits grow in abundance, their significance is seldom fully appreciated. Locals consider them merely free wayside snacks for enjoyment alongside the roads, paths, and trails they take to school, to town, to the bus stop, or to the pastures. Outsiders, notably scientific investigators, have often been misled because people so fail to value wild fruits they go unmentioned in such things as socio-economic and nutritional surveys. Also, strangers from the city or a foreign country typically measure only the foods in the house and "on the table." To them, the idea of a separate world of foods snatched from living nature could seem unimaginable. Sometimes, also, outsiders are victims of translation mistakes. In a number of African languages, for example, the local word generally translated as "food" refers only to cooked items, and therefore omits wild fruits.

There have been few concerted efforts to physically integrate wild fruits into the mainstream of dietary development. Despite being integral parts of traditional culture, these are one of the most neglected of all African resources. To advance the greater use of wild fruits is an exciting area with high possibilities for benefiting scores of economies and millions of people.

And the challenge may not be as great as might initially be assumed. Many of the following chapters attest that landowners already have a high regard for certain trees that produce wild fruits. Africa's traditional shifting agriculture usually aims less at destroying such trees than cutting them back while keeping them alive. This is seen across many savanna areas. Of course some plants die when cut, but many re-grow from the stems and stumps, and thus provide a tree fallow that covers and protects and restores fertility to the site for the next round of crop planting. For this purpose, "edible" trees are in many places singled out for special protection.

This is a valuable method of producing food, but increasing population pressure is seriously shortening fallow periods. Even stumps that re-sprout best are weakened and stressed beyond their limit if cut back too short or too often. A fast return to a fallowed site also reduces natural regeneration rates by retarding growth of plants too young to resist fire. Overgrazing is also a factor reducing natural regeneration rates. In addition, the wider use of animal traction or small tractors requires that stumps and roots be removed from cleared fields. And in forest zones, commercial logging opens land for shifting agriculture, meaning an expanding landscape where most species are stressed. Emphasizing wild fruits adds value to nurturing all such lands.

Even small improvements in awareness of bush fruits might well bring big benefits to localities in which they grow. Increments that perhaps seem insignificant could eventually be lifesavers to societies on a nutritional edge.

Exploring the greater use of the wild resource offers opportunities for innovations of the most far-reaching kind. Edible wild plants might, for example, be utilized for purposes such as groundcovers, shelterbelts, street trees, windbreaks, hedges, roadside screens, or erosion barriers. People (and especially children) could then, as in the past, find nourishment on every hand. It is not difficult to imagine the establishment of "edible parks," "edible watersheds," wild-food reserves, year-round fruit gardens, "edible fallows," and street trees and hedges selected so as to provide a year-round cornucopia of "kid's treats." Such notions are especially important for towns and cities, as other parts of the tropical world have learned. Even in the center of Quito, Ecuador, for instance, bus stops usually have a native capulí cherry tree beside them. This is mainly to provide shade and beautification, but schoolchildren feed themselves as they wait for the ride home after a day in the classroom. In southern Mexico, many town squares are planted with mango trees that provide food and drink to kids as well as many adults (especially the poor). And in India, an African fruit tree, the tamarind, lines thousands of rural roads, paths, and highways, mainly for shade and shelter but partly to sustain the hungry.

DEVELOPING WILD FRUITS

Keeping wild fruits wild is certainly an important aspect of the future for Africa. But many of the native fruit species also seem to be good candidates for improvement, domestication, and commercial production. Awaiting the adventurous plant scientist and eager amateur are opportunities to create a new cultivated crop and possibly transform their own lives in the bargain.

The limitations of propagation can be overcome more easily today than ever before. And the entry of traditional products into long-distance trade is also easier than ever before. Thus in the decades ahead the world of African fruits could be made afresh.

For developing most of these species, the first requirement is selection—location and propagation of individual plants that yield superior fruits. Some features that make a superior fruit include large amounts of edible pulp, small numbers of small seeds, attractive colors, marketable size, appealing flavor, low stringiness, freestone features, resistance to pests and diseases, and long shelf life. Perhaps most important is yield potential, for this is what puts money in the grower's pocket and incentive in the grower's head.

Tropical fruit trees must be approached across a broad front because the majority of specimens are not worth propagating—neither are the majority of wild apples, oranges, peaches, kiwifruits, and the rest. With most tree fruits, mass propagation of single "elite" specimens can turn a commonplace

minor fruit into a major contributor. Oftentimes, only one plant in 10,000 (or many more) will bear such elite fruits. To find that one special plant, a person need not be a botanist, horticulturist, or other specialist. Indeed, the "loner" in a remote valley has a better opportunity of locating a winner in that genetic lottery than the scientist in the capital.[6]

With so much potential in wild fruits, many approaches to developing the resource are possible. In one, for instance, interested individuals could organize an "African wild-fruit development association." Chapters could be established in different countries, or in the cyberworld. Their purpose: to save and share germplasm, to exchange results, to inventory various promising locations, to gather folklore, as well as to stimulate broader interest, to develop recipes, and, most of all, to get superior types into hands of villagers, landowners, marketers, exporters, and other potential users. This requires little or no government funding, and indeed might be more freewheeling, more dynamic, and more successful if it springs from grassroots operations organized and energized by enthusiasts. Schools could be encouraged to record yields, pollination methods, lifecycle stages, and so forth. This approach has already shown success in Botswana, where a small company organized a nationwide competition amongst school children to find plants with the biggest and sweetest fruit of selected species. Substantial prizes were given. The results were rewarding, producing fruits of exceptional quality that are now being promoted for the country's benefit.[7]

Such generalized activities, while important and likely to bring success and satisfaction, can go only so far. Africa's wild fruits offer such a wealth of benefits that formal research programs should also be set up all over the continent.[8] In that way, horticulturists, plant pathologists, soil scientists, entomologists, foresters, and others can apply their training and experience to develop wild fruits. Examples of some specific technical needs are to:

- Reduce the often-long delay between propagation and first fruiting.
- Reduce the often-long delay between flowering and fruit maturation.
- Identify early-, middle-, and late-producing, superior genotypes for development into cultivars.
- Find how to propagate (both through seed and vegetative means), germinate, plant, and grow recalcitrant species.

[6] It was an Australian housewife who discovered the 'Granny Smith' apple in the 1860s. The seedling popped up in her backyard after she had tossed out some old fruit. She recognized good taste and cooking qualities, and today it is one of the world's major apples. Her name was indeed Smith and she was a grandmother.

[7] Recent information on this initiative can be found at www.veldproducts.org.

[8] The "Cinderella Tree" initiative of the World Agroforestry Centre in Nairobi (www.icraf.org) for domestication and commercialization of multipurpose tree species was a good example of this thinking, which seems to be taking hold among the broader research communities.

- Select desirable traits and specimens for propagation.
- Determine the limits—geographic, phenologic, edaphic, and climatic—where a species can be successful.
- Develop horticultural techniques—pruning, grafting, top-working, hybridizing, maintenance, orchard management, and more.
- Develop ethnobotanical, horticultural, extension, vocational, or other appropriate curricula for school levels from entry through post-graduate.
- Learn how to protect the plants from pests and pathogens.
- Undertake cultivar trials to prove efficacy of superior genotypes.
- Establish demonstration plots.
- Preserve the sources of wild fruits.

The involvement of professionals does not obviate the need for the grass-roots plant-lovers. Both offer much. Indeed, the collaboration between eager amateurs and devoted professionals has been a most successful one in the United States, where several societies of rare-fruit enthusiasts (of all age groups and walks of life) work together to introduce new fruits to the nation, with much enjoyment and personal satisfaction along the way. Exemplifying what can be done is the Florida mango industry, in which enthusiastic amateurs selected most of the cultivars. California's avocado and date industries began similarly with amateur initiatives, as did several Australian fruit resources, including passionfruit, custard apple, and macadamia.

NUTRITION

In the exploration of wild plants there is of course much need for laboratory scientists in disciplines such as nutrition and food technology. Despite the importance of nutritional composition data, many of the wild fruits have gone unrecorded. If made available, nutritional information alone might convince planners of a species' promise and potential. It is vital, therefore, to develop a nutritional database for the most important edible wild plants.[9] For a relative pittance (at least in terms of today's research budgets), this could create nutritional and economic returns beyond measure. Indeed, a concerted program of information or education would likely transform the way rural people regard the small, concentrated-in-flavor fruits they find around them and often spurn. And along with the realization of the importance of wild fruits could also come care and concern and commitment to their greater protection and greater use. Helpful here could be the precedents of a dozen or more nations (from Scandinavia to Chile) that publicly disseminate depictions of nutrition pyramids or piecharts to induce consumption of local fruits and vegetables and a more balanced diet.

[9] We wish here to recognize the pioneering work of A.S. Wehmeyer, who in a lifetime of dedicated scholarship recorded the basic nutritional constituents of over 300 of South Africa's edible species.

SUSTAINABLE FORESTRY

Africans' abiding interest in food trees could be made into a driving force for future forestry efforts. The problem is that foresters have traditionally dismissed such species. In their eyes these may be woody plants but they typically have "bad form" (that is, trunks not long and straight and properly rounded for the best production of timber). And they think of any food-producing tree as belonging to the alien sphere inhabited by horticulturists.

Yet many of Africa's wild fruits come from native forest trees. Of 1,000 indigenous trees growing in southern Africa, for example, more than 200 produce fruits eaten somewhere or another.[10] Those tree-fruits may be eaten raw, dried, or mashed into paste; they may be eaten for health, hunger, or pleasure; they may be tasteless, astringent, or downright delicious. These comprise a vast forest food reserve, and such deep-rooted resources are urgently needed in these days when maintenance of trees is taking on greater and greater importance in sustaining a balanced environment.

One particularly innovative concept, "salvation forestry," might well soon employ wild fruit trees. In this system, local people produce products in the forests in ways that ensure them a stake in the profits. The goal is to help the villagers to become so dependent on natural forest bounty that they become the fiercest of all conservationists.[11] Perhaps there may also be ways to get credits for carbon sequestration or contributions to the conservation of biodiversity. Since only the fruits are harvested, these trees could also be seen as ideal for long-term credit schemes.

Such local support is crucial because many countries are so overcrowded that poor people are spilling out into the forests and savannas in never-ending numbers. In the past, authorities attempted to protect endangered systems behind the guise of exclusionary laws, but even the best-run nations lack the massive resources needed to enforce legal protections in remote areas. Moreover, many of the rural peoples feel driven toward the food or cash they can get from turning forest into farmland. There seems no practical way to thwart millions, especially when they are desperate to survive.

Salvation forestry, however, has a chance of succeeding. It is a "supply-side conservation" in which threatened areas now pay their way to survival. This approach is being adopted in several parts of the tropics. The organized use of wild tree-fruits could well improve the effectiveness of hundreds of efforts to conserve Africa's wooded habitats.

For these reasons, tree fruits should be incorporated into environmental programs, agroforestry, forestry, agricultural projects, and programs dealing

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[10] Palmer, E. and Pitman, N. 1972. *Trees of southern Africa, covering all known indigenous species in the Republic of South Africa, South-West Africa, Botswana, Lesotho & Swaziland.* A.A. Balkema, Cape Town.

[11] The Food and Agriculture Organization's (www.fao.org) initiative for Promotion and Development of Non-Wood Forest Products has been one of the leaders in this area.

with sustained food security for the peoples of Africa. Taken all in all, wild tree fruits are good for the environment, good for the people, and good for national stability in all nations, but most especially in those under-nourished and under-performing climes that fall below the Sahara.

SOCIAL DIFFICULTIES

Of course, in developing fruit activities, obstacles will intervene. Some could arise from social issues confronted by any tree planting effort in Africa, including questions of tenure and of the traditions of planting or owning trees. Other obstacles will arise from traditions concerning specific tree species. The very act of valuating what was essentially a free foodstuff will require careful evaluation of habits and community customs. In countries where national forest services have a mandate to protect naturally occurring trees, including those which bear fruit, clarification of ownership of wild fruit trees planted by individuals or communities may be necessary.[12] Should wild fruits ever become economically valuable on a level approaching that of mangos and citrus a new set of issues come into play. For example, grower's need access to the land on which their trees are planted, so as to protect and benefit from the investment of time and money over the decades the trees remain productive. Many such social challenges must be considered when pursuing development of wild fruits.

It is important also to realize that customary practices and even superstitions still play a strong role in the lives of many rural peoples. For example, in places some tree species may be designated for the use of specific groups. Similarly, the land-tenure system, in which land is communally owned (and also its resources, including trees for fruit), may militate against individual people planting trees. In some societies, such an act could arouse jealousy and suspicion and perhaps incur wrath by flouting inherited authority to "parcel out" land. A stand of trees, after all, implies permanency of tenure.[13]

So, research on wild fruits should take account of both the sociocultural systems in which the trees occur and the farming systems in which eventual cultivation of these trees might have to fit. This multiple-use feature is of special significance. One of our most experienced contributors—a botanist with a long lifetime's experience with African plants—wrote: "In general I feel that your search for food crops in Africa, in particular useful fruits, may be in vain. There are so many exotic fruit trees available that further new ones may be unlikely to repay the cost of development." But then he added

[12] It is interesting to note that the legal right to use and enjoy the advantages or profits of another's property, called "usufruct," arises from the Latin phrase for "use of fruits." It also bears the proviso that the property not be damaged or altered in any way.

[13] For thoughts on these matters we want especially to thank B.N. Wolstenholme, who added, as if to reassure us, "These problems are real!"

as an afterthought: “As I think over the matter, I realize however that while there may be few plants worthy of cultivation *purely* for their *fruits* there probably are quite a considerable number worth growing on a *multipurpose* basis. Among the uses to be considered: fodder for reserve use in time of drought; sticks for hut building and so forth; wood for carving; fiber; medicines; honey and beeswax; bark; roots; and seeds for protein and cooking oil. All these are often more useful than are the fruits eaten for taste, minerals, and vitamins.”

In the view of this panel, it is worthwhile pursuing the full plethora of possibilities offered by the wild fruits of Africa—consumption and commerce, as well as whatever else can be made from the plant or its byproducts. For too long, the spark of modern ingenuity has ignored these ancient foods.

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The potential of Africa’s wild fruits to improve its quality of life has been emphasized in the summary outlines above, but they are also constrained by various limitations, all of which are discussed in greater detail in the chapters that follow.

DESCRIPTIONS AND ASSESSMENTS OF INDIVIDUAL SPECIES

1

AIZEN (MUKHEIT)

The aizen or mukheit (*Boscia senegalensis* (Pers.) Lam. ex Poiret) occurs across the very area that in recent decades has faced more hunger than any other in the world—the vast swath of Sahel and Sahara savannas stretching from Mauritania, Senegal, and Mali all the way to southeastern Egypt, Sudan, Ethiopia, Somalia, and Kenya.

This highly stressed and unforgiving region provides some of the most daunting conditions ever faced by higher plant life. Yet this is the aizen's territory. In extreme aridity it shrinks to a scrawny shrub less than 2 m tall, but in favorable environments it soars several times that height and becomes almost treelike with a rounded, spreading crown.

Having survived thousands of years of recurrent drought without horticultural help, this wild species holds the potential to make life more bearable under the desiccating conditions in which millions of Africa's most destitute are increasingly forced to exist. For this, there are at least three reasons. First, aizen is adaptable, resilient and, of course, capable of handling extreme drought and heat. Second, it yields an array of useful products. And third, it provides year-round shade in areas where even slight relief from the sun seems merciful.

Aizens are not fruit crops in the normal sense. It is the combination of foods and useful qualities that makes them important. The species produces enough different products to sustain human life almost by itself. In at least a dozen countries, at times people virtually live off aizen fruits, aizen seeds, aizen roots, and aizen leaves. In eastern Sudan, for example, men and women sometimes spend 8 hours a day seeking aizens, carrying the branches and fruits home to ease their hunger or sell along the roadsides to other hungry people. For them, these plants are crucial to existence, allaying hunger and earning cash. Also, the foliage keeps their animals alive during the dry months when little remains to sustain a herbivore. And certain peoples use various parts of the plant for cooking food, controlling pests and parasites, and clarifying water to render it safer for drinking.

Although not unpleasant on the palate, the fruits are most notable for being on hand when little else edible remains. The foliage's very unpalatability is key here: livestock and wildlife leave aizen alone for most of the year. Thus the human users have no worries that their trees will be

Zinder, Niger Republic. Aizen occupies some of the hottest, driest locations ever faced by plant life in the modern era. Yet it not only survives, it yields enough useful products to sustain human life almost by itself. In at least a dozen countries, people virtually live off aizen fruits, seeds, roots, and leaves. The bushes typically give a lot of fruits, which mostly ripen at once. The fruits shown here are unripe, and would normally be collected only after they turn yellow. But because of the food shortage, people are often unable to wait that long. (Eden Foundation)

destroyed by the desert or devoured by goats or gazelles. For this double security alone, aizen is promising for establishing famine-food reserves, for protecting erodible soil, for stabilizing dunes, for windbreaks, and for other utilitarian purposes in the harshest of harsh sites—ones where people need every last bit of help in the struggle to survive.

This plant's endurance is remarkable. It tolerates shade temperatures as high as 45°C, a level not rare in its habitat. It occupies most types of arid-land environment: stony slopes, sand dunes, and cracking-clay plains, just for starters. It often occurs in desiccated, barren, hard, and even fire-scorched sites. As to soils, they are usually poor, sandy, rocky, worn-out laterite, or clay. Commonly it sprouts directly out of termite mounds. And it survives in areas receiving as little as 100 mm annual rainfall, although it grows best where there is at least 250 mm. Contributing to the plant's built-in drought tolerance is its remarkable leaf structure: the cuticle is up to 20 microns thick, the stomata are sunk in deep cavities, and each stomate has thickened walls and a protective armoring of papillae.[1]

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[1] Killian, C. 1937. Contribution à l'étude écologique des végétaux du Sahara et du Soudan tropical. *Bull. Soc. Hist. Nat. Afrique du Nord* 28:12-18.

For all such reasons, this nondescript "ugly duckling" is in humanitarian terms one of the most admired of all trees. When in recent years researchers surveyed local food and forage species, aizen proved to be the most popular food source among all the indigenous trees in Niger.[2] During the 1984-1985 famine in Sudan it was by far the most widely used famine food.[3] According to one analysis, 94 percent of people in northern Darfur who had access to aizen (mukheit) during the famine consumed it.[4] In fact, during the famine a market developed in which it effectively replaced sorghum and millet (esh) as the staple and those normally basic grains became luxury foods.

Perhaps it is not so surprising that people like aizen fruits. At least six parts of it can be put to use, and most of those can be lifesavers. Further, aizen trees are used in at least four ways that relate indirectly to food production. All these are mentioned below.

Fruits The yellow cherry-sized berries (up to 1.5 cm in diameter) are borne in clusters. When newly ripe, their rather sweet pulp is translucent and jelly-like. However, in the desiccating air it quickly dries out, turning into something not unlike caramel before ending up a brittle, brown, and quite sugary solid. Despite its good taste, this toffee-like treat is difficult to separate from the seed.

Although the fruit is a seasonal food, its season differs from the norm and comes at the beginning of the rains, a time when farm crops are just being planted and anything to eat is usually difficult to find. This alone makes aizen a lifesaver.[5] In the better-watered zones, where there are many edible plants to choose from, aizens serve mainly as supplementary, rather than staple, foods. But still, these fruits remain inestimably valuable backups for the devastating drought emergencies that arise almost routinely every decade or two.

Besides being eaten fresh, the ripe fruits are often boiled. Furthermore, sometimes juice is extracted, filtered, and boiled down into "aizen butter," a semisolid commonly mixed with millet and curdled milk to make "cakes."[6]

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[2] Information from Timothy J. Johnson and Michele Rodrick.

[3] Salih, O.M., Nour, A.M. and Harper, D.B. (1991) Chemical and nutritional composition of two famine food sources used in Sudan, mukheit (*Boscia senegalensis*) and maikah (*Dobera roxburghi*). *J. Sci. Food. Agric.* 57 367-377. Also, Omar Mohamed Salih Abdelmuti (1991) *Biochemical and Nutritional Evaluation of Famine Foods in the Sudan*, PhD thesis, University of Khartoum.

[4] de Waal, Alex. 1989. *Famine That Kills: Darfur, Sudan, 1984-1985*. Clarendon Press, Oxford.

[5] As contributor Paul Beckman wrote: "The fruits are usually ripe in the area around Eden's field station near Tânout, Niger, for two months during July-August. This is in the rainy season but it is a critical period when food stocks from the previous harvest are at their lowest."

[6] Sometimes the juice is extracted by loading a pile of aizen fruits into the panniers carried by donkeys. The jolting does the job.

Detailed nutritional analyses seem unavailable, but the fruits are reportedly rich in calcium, phosphorus, iron, and B vitamins.[7] They are also said to contain a little protein.

Seeds Each fruit usually has one or two greenish seeds, which look like peas and are used like peas. They are in fact the more important foodstuff. Throughout the Saharo-Sahelian zone they are such common items of diet they are sometimes described as desert dwellers' staples. They, too, are important famine-time foods. And roasted, they also substitute for coffee.

After extracting the juice from the fruit, people typically separate the seeds from the pithy residue, dry them in the sun, and put them aside for safekeeping. In times of scarcity, such as at the bitter end of the dry season, these dried seeds substitute for millet or lentils. They require lengthy preparation and must be eaten cooked. The traditional procedure involves soaking the seeds for a week (changing the water daily) to remove bitter components. Less commonly, they are boiled 3 hours (and rinsed at least twice with new water). In either case, they are subsequently dried and ground into flour. This aizen-seed flour commonly replaces sorghum, millet, or lentils in making porridge.

Nutritionally speaking, the seeds are satisfactory. Starch and soluble carbohydrate content compares favorably with local staples (sorghum and millet). The protein content is high relative to those cereals and the protein quality (chemical score 33) is similar to that of sorghum (chemical score 36). As to minerals, the seed has exceptional amounts of sulfur and zinc.[8]

Roots Young roots, scraped of bark, may be ground, sieved, mixed with cereals, and boiled into a thin gruel or thick porridge. They are very sweet. Some are dried in the sun and kept on hand for hungry times. Root tissues are also boiled slowly for several hours to make syrup.

Leaves The leaves, although just about the most leathery and least appealing foodstuffs on earth, are also consumed. Most are dropped into soups or boiled and mixed into cereal products such as gruel or couscous. The plant is particularly useful this way because it is an evergreen and provides food and nutrients when other plants are bare.

Flowers The flowers provide bee forage, often in areas where little else capable of sustaining honeybees is available.

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[7] Wickens, G.E. , J.R. Goodin, and D.V. Field, eds. 1984. *Plants for Arid Lands*. George Allen and Unwin, London.

[8] Information from D.B. Harper. The protein quality mentioned was for seeds that had undergone a soaking treatment. The boiling process improved the quality of protein (to a chemical score of 49), but reduced the overall protein content. Assuming the bulk of the sulfur is present as sulfate, the seeds contain about 6 percent sulfate on a dry-matter basis.

Zinder, Niger Republic. A food security gem, this fruit has been a proven lifesaver during famines from ancient times right up to recent days. Within recent memory it has preserved many lives in the Sahel as well as during the subsequent famines in Sudan and Ethiopia. The fact that livestock and wildlife ignore aizen for most of the year removes one of the hazards of wild foods. And the trees resist destruction even by the desert. For this multi-layer security, alone, aizen is extremely promising for establishing famine-food reserves. (Eden Foundation)

Wood Aizen wood is cut for poles, notably those holding up houses. Although smoky and stinky, it is used as cooking fuel when nothing better is at hand (which in the harshest areas is all too often).

Forage Unpalatable as the fresh foliage is, aizen is nonetheless a vital feedstuff. There is a strange paradox in the fact it is good because it is unpalatable. In fact, its very repulsiveness is its strength: When all else has been eaten up, aizen keeps cattle, sheep, goats, camels, and donkeys (not to mention gazelles and other wild creatures) alive. It is what might be termed "famine forage." Although the need for such a fallback-forage may be brief, it may be vital. Livestock cannot be dried and stored on the shelf like fruits; they must of course be fed year-round. A few scrawny aizen bushes providing sustenance for a few weeks or perhaps a few days may be all that stands between the animals and death.

Pest Repellent In some parts of the Sahel, aizen leaves are added to granaries to protect stored foods against pests. This long-standing traditional process seems to work. Given some study, it might prove to be yet another way this plant can contribute to food supplies and food security.

Water Clarification Aizen contains natural coagulants. In Sudan, Niger, and Nigeria, for example, bark, twigs, leaves, and roots are used to scavenge suspended and colloidal compounds from unclean water (such as that from ponds churned up by storms or from baobab-tree cisterns contaminated with soil). Normally the plant parts are sliced up and placed on the water surface. Compounds leach out and catch the clay and other particulates like magnets, causing them to clump and settle to the bottom. It is reported that truly turbid water can be safely drunk after just a day of such treatment. For even faster results, aizen branches are swirled in the water. Indeed, certain Tuareg groups in the Sahara region fill sacks with aizen leaves and dunk them into the muddy pools that comprise their only source for drinking. Following a rare desert downpour they may also place these giant tea bags across ditches so that the runoff clarifies itself as it oozes through.[9]

NEXT STEPS

Considering the desperate international efforts to feed people in the area where aizen grows, this plant deserves much greater support than it presently receives. Although it has not yet been subjected to horticultural attention, it is promising wherever in Africa desertification is a threat or a reality. Having a reliable backup on hand for the worst of hungry times would be a step toward stability for that part of the world that has absorbed billions of dollars of food aid during recent decades, and yet still lacks a reliable food base.

Despite all this promise, however, much fundamental research remains to be done before aizen projects can be launched with confidence. Some practical steps and basic fact-finding endeavors are the following.

Build Up Wild Stands One direct approach toward improving food security for Africa's most vulnerable regions is to rescue, revive, and redevelop the individual trees and existing stands of aizen. Farmers tend to respect areas carrying this species, and their bred-in-the-bone interest can be harnessed to solidify thousands of local stands.

This is a good endeavor to start an aizen program with: 1) it avoids the delay of waiting for the trees to grow and mature; 2) aizen's presence shows that at least the terrain, soil, and moisture are not in doubt; and 3) probably, the site will not be overgrazed. Hence restoration programs are more likely to be immediately successful than new plantings.

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[9] Although water clarification is an important feature, moringa (see companion report on African vegetables) does better. However, aizen thrives where moringa cannot survive.

Food Security Rescuing aizen stands provide excellent opportunities for relief programs among the destitute. Again, locals should see a lot of self-interest in the work, and will likely participate with enthusiasm, not to mention skill and care. According to a Sudanese famine-food specialist, aizen was the "number one" famine food during the horrific 1984 famine in the western Sudan. "It proved to be people's lifesaver," he reports, "and it saved more lives than all the food aid that was given."[10]

Given an experience like that, aizen should be not only preserved and protected, it should be planted out in big blocks throughout the drought-threatened regions of the Sahel, Sudan, Somalia, and Ethiopia. Not only would these plantings protect the land, they would provide famine reserves for the future droughts to come. Global reforestation activities today largely focus on rainforest regions and temperate zones, but reforesting the drylands might bring the greater benefit, at least in humanitarian terms. Though aizen is today very far from any forester's ideal, it could be a key for opening the reforestation activities across Africa's hungry drylands. The trees may look terrible to a forester, but their benefits could nonetheless be sublime.

Although the seeds germinate readily, the seedlings have so far proved difficult to transplant from nursery to field. Thus, it is recommended that direct-seeding trials be established to find out how to establish healthy populations in situ.[11]

Aizen is of course important to the natural environment, providing wildlife with a last-ditch forage supply. It is sometimes all that animals can find to eat; everything else being dead, dying, dormant, or too desiccated to digest. Expanded plantings will therefore bring benefits beyond purely humanitarian ones.

Gather Germplasm No scientific authority has reported on the genetic diversity in *Boscia senegalensis*. At present, the variability is dispersed and known only to local individuals. This traditional knowledge could point to immensely valuable variants relating to fruit size, sweetness, and at least a dozen other features. The key is to assess this decentralized wisdom and to locate the best individual plants. Contests and cash prizes would likely winkle out surprising genetic variants. Seeds from these could be collected and made available especially for use in these self-same regions threatened by disastrous drought, including the Horn of Africa and the Sahara's sharp southern edge. This is a big undertaking but their own knowledge–coupled with science–could make one of the greatest contributions to these same peoples, among the most vulnerable in the world.

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[10] Information from O.M. Salih Abdelmuti.

[11] Direct seeding is already being advanced by the Eden Foundation (eden-foundation.org), a Norway-based charity operating out of Zinder, Niger.

Horticultural Development At this point aizen's ultimate contribution as a resource is anyone's guess. It is hard to assess the potential of any food crop when there exists neither agricultural trials nor any estimate of yield. One certainty, however, is that the much abused specimens now populating the dry zones around the Sahara are poor indicators of the species' potential. Indeed, considering that the species has not been domesticated, there should exist opportunities for improving everything from yields to palatability. Once superior types are identified and mass propagation worked out those improvements can occur with a rush.

Although details are uncertain, there are claims that root and shoot cuttings have been used to propagate aizen. This could be a vital lead because with them superior plants can be replicated. Also grafting should be explored, because it would allow elite aizen types to be grafted onto the wild trees now so prevalent and widespread. That in turn would ensure rapid quality-fruit production. Also, it would provide lasting benefits because of the rootstock's obvious adaptability to the site.

Analyze Current Usage Aizen offers much potential for anthropological studies, especially in the hunger-prone regions. There have been studies already, of course, but those were sweeping assessments of all the so-called famine plants. Now is the time to focus specifically on this particular plant. It is clearly a leader, and the specifics awaiting documentation are likely to be surprising.

Nutrition and Food Science A major immediate need is for toxicological tests. Toxicity in the fruits seems unlikely considering that they are such a common food. But the seeds are certainly bitter and may prove unsafe. Given the fact that poorer families rely on the flour from dried aizen seeds, researchers should investigate and determine what (if any) toxic compounds are present. Helpful here, also, would be public health surveys of possible harmful effects on the people who eat aizen fruits in quantity. Analyses should also be made of the various processes used to remove bitterness. This would clarify whether or not such lengthy preparations (or even more lengthy ones) are needed to make the seeds edible.

Similar toxicological tests should be performed on leaves. This will settle (or confirm) doubts about their use for feeding both people and animals.

Pest Control The aforesaid fact that aizen leaves are used to protect grain against pests deserves at least preliminary investigation. This is exactly how neem is used in rural India. Over the past few decades researchers have followed up that lead and their work has led to the use of neem in countries as far away as the United States, where the seed-extracts have environmental approval and are now considered a wonderful new organic pesticide.

FAMINE FOOD

In famine times, people in rural Sudan rely on aizen. Typically, they collect the fruits, sun-dry them, separate the pea-sized seeds, and remove the hard outer seed coat. Seeds are then subjected to “sweetening” to remove bitter and possibly toxic components. The traditional procedure involves soaking for a week, changing the water every day. Sometimes “kambo,” a local potash prepared from plant ash, is added to aid the debittering. Less commonly, sweetening is conducted by boiling for 3 hours, with the water changed hourly. After such treatment, the sun-dried “sweet” seeds are stored until required, at which time they are boiled until soft, changing the water once during the process. The resulting food is usually eaten with oil and salt. Alternatively, seeds are ground to a flour which is consumed in the form of kisra, a flat thin bread popular in Sudan or asida, a local form of porridge. The taste of the final product can be improved by blending with millet or sorghum flour. (D.B. Harper, Eden Foundation)

Anti-Desertification Trials As already noted, aizen’s helps people survive in some of the most desolate, dry, and infinitely difficult regions.[12] Preserving aizen along the Sahara margins could be a first practical step in

[12] For instance, when crops failed in the western Sudan (Kordofan) way back in 1900, aizen fruits were fed to the people and apparently this is what kept them alive in that era before rock stars and airlifts could rush in support from the world outside.

AIZEN BY ANY OTHER NAME

This plant goes by innumerable common names. Aizen (sometimes spelled ayzen) is a Berber word and is the one most commonly used in the literature dealing with West Africa. Other names include mandiarha (Berber); mokheit, mukheit, umkheit (all Arabic), bere (Bambara); ngigili (Fulani). Other common names for the fruit include dilo (Hausa); bokkhelli and kursan (Arabic); gigile (Fulani); tadahant, tadent, tadomet (Tamachek); harrenya (Sonrai); nabedega (More); and nkiandam and diendoum (Wolof).

The genus is named for a French biologist, Louis Bosc (1759-1828). During the French Revolution he was rendered destitute and imprisoned for the obvious crime of possessing a father who'd been King Louis XIV's doctor. In 1796, however, he was reinstated and sent to the United States as his country's consul. There (particularly in North Carolina), he did most of his botany, eventually naming some 600 North American species. Later, when the Swedish botanist Carl Peter Thunberg—today recognized as the "Father of South African Botany"—discovered a new genus of plants at the Cape of Good Hope, he named it *Boscia* in tribute.

reversing the destitution caused by desertification. And the power of this plant is not just stopping expansion of desert conditions; aizen could be a prime offensive weapon for active reclamation of lands that now seem lost.

In this regard, trials with planting seeds and/or cuttings into sand dunes should be carried out. Aizen is commonly the last vegetation left before the desert takes over, so there is hope that it could be the first vegetation in the process of taking the land back from the desert's grasp.

AIZEN RELATIVES

The genus *Boscia* includes almost a dozen species bearing edible fruits of reasonable size in Africa. Various of these species are to be found across the continent. Most of them populate open savanna, but can also form a thick understory in woodlands and dry forests. Possibly all have merits as future foods, but now is the time to focus on the few showing immediate promise. Research to clarify the genetic differences, as well as test plantings to identify different ecological requirements, are particularly suggested. Perhaps cross-pollinations between species will yield useful hybrid products, such as seedless fruits or extra-vigorous trees that grow fast and yield above-average fruit harvests.

Below we highlight two of the better-known aizen relatives.

Boscia angustifolia A. Rich This species, too, is found in the huge belt stretching from Senegal to northern Nigeria, but it occupies an area just to the southward of aizen. It also extends at least as far south as Malawi. In many places it is more common than aizen, and the two are often confused. Although its roots are inedible, people often dig them up in the mistaken belief that they are aizen roots.

Although quite edible, the fruits are bitter. The seeds are cooked and then eaten. Even the bark is supposedly edible. Powdered and mixed with millet flour, it is added to soups or cereals.

The plant is browsed by herbivores, although somewhat reluctantly. Nevertheless, it is a *very* important browse plant for livestock, notably for goats, sometimes sheep. Trees are heavily lopped, especially at the end of the dry season, as a way to keep the herds from starving.

Boscia albitrunca (Burch.) Gilg & Gilg-Ben. **(Shepherd's Tree)** Perhaps Africa's second-best known *Boscia* species, the shepherd's tree or witgat is widespread in drier sections of southern Africa. It is found, for example, throughout Namibia and South Africa, as well as in parts of Angola, Zambia, Zimbabwe, and Mozambique. It mainly occurs in savannas and bushveld. Dubbed a "tree of life," it provides nourishing fodder for game and livestock and water for people. The San, for example, seek out its old hollow trunks for the water they hold. Many African groups regard this tree so highly they forbid anyone destroying it. In times of drought, herdsmen cut off the branches or bend them within reach of grazing stock; hence the name "shepherd's tree."

The smooth-skinned, cherry-sized fruits are orange-yellow when ripe. They are rather acrid in taste and have slimy flesh, but are nevertheless widely and eagerly eaten. Although having a short shelf life, they are easily preserved in the form of a tasty jam or syrup. Soaked in water, they produce a sweet drink. Some are also crushed in fresh milk to make a pleasant treat.

Surprisingly, the roots contain sugar…a lot of sugar. In Botswana, they are widely used to make sweet drinks. The bark is scraped off, the inner tissues are pounded to separate the coarsest fibers, and the resulting cassava-like pith dried in the sun. When needed, this white solid is pounded to a powder and boiled with water until it resembles syrup; on cooling and diluting it is ready to drink. The young roots are also roasted, ground, and used as a coffee or chicory substitute.

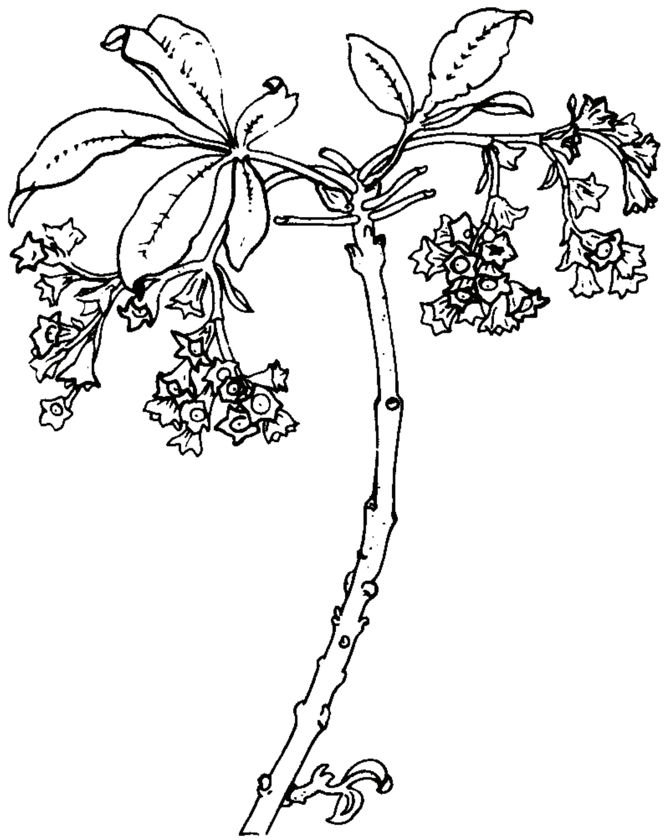
This attractive plant produces an abundance of small, sweet-smelling flowers. The flower buds may be pickled in vinegar and used like capers. For this reason it is also known as caper bush.[13]

[13] Both it and the capers plant belong to the same family, Capparaceae.

South African research (carried out by the CSIR's Division of Food Science and Technology) has shown that the root kills fungi well enough to be used to preserve food. Local people have long known this; the use of root slices to keep butter and other foods from molding is of long tradition.

This small tree is important to the lives of millions of domestic and wild animals, especially in drier areas. Cattle, goats, birds, monkeys, antelopes, and even elephants devour the fruits and leaves, which are said to be exceptionally high in protein and vitamin A.

The shepherd's tree might prove useful for supplementing the aizen in the Sudano-Sahelian zone.



Vitex zeyheri

2

CHOCOLATE BERRIES

Of the nearly 70 *Vitex* species found scattered across tropical Africa, at least some are of local commercial and nutritional importance. These small and rugged trees are quintessential wild foods. In season, they become bespangled by an abundance of blackish fruits, which passersby eagerly gather up. Part of the harvest is eaten there and then, but most goes to market for sale. The reason? Although newcomers may loathe the pungent scent and brown stain on the lips, almost everyone loves the "chocolate" flavor.

Unknown beyond Africa, these particular *Vitex* species, from the mint family (Labiatae), are essentially unknown to science too. But they are so useful that without them life would be even harder in many places between Senegal and South Africa. You see, villagers rely on these trees for much more than just fruits. They boil and eat the young leaves like spinach.[1] They depend on the foliage to keep their livestock from starving during the long and trying months when the grass is gone. They use the twigs as chewsticks to clean their teeth. And they visit the trees to obtain medicines.[2]

Beyond all that, these supremely utilitarian species produce a straight-grained timber resembling teak. It is used for the walls and roofs of houses as well as for furniture, boats, crates, bowls, stools, shelves, and (at least in Uganda) chairs, drums, and knife handles. It also makes good firewood and is said to be good for rubbing together to start a fire by friction.

For all these reasons, these rugged, robust, and resilient woody plants seem excellent candidates for further development and more organized use. They are obviously not solely horticultural resources: their greatest value, eventually, may be not to fruit growers, but to livestock owners and to foresters. For this last, they are especially promising because people eagerly plant and tenderly nurture any quality seedlings supplied. Everyone likes

[1] The resulting food is called dinkin in Hausa.

[2] This may not be without merit. In 2001, the *British Medical Journal* (*BMJ* 322:134-7) reported on the effects of extracts from the fruit of the "chaste tree." In the study, 170 women took this preparation over three menstrual cycles. More than half showed less irritability, anger, headache, and breast engorgement—classic manifestations of premenstrual syndrome. The study's authors speculate that the tree has hormonal properties and also acts directly on the brain. Its scientific name: *Vitex agnus-castus*.

Central African Republic. A chocolate berry (species unidentified) locally known as mbili. (Roy Danforth and Paul Noren)

having a chocolate berry tree[3] around. Some already go out, gather the seeds, and deliberately plant their own. For such reasons, these species likely have exceptional promise in agroforestry and rural reforestation, and they might perhaps become standard components in the mix of species employed to stabilize eroding slopes and abandoned wastelands across much of the continent. Among other advantages is their longevity. These trees are never cut down irresponsibly. Even the wild ones are protected by societal rules.

Those traditional rules have a good social purpose. Almost everyone—not to mention the environment—benefits from the living trees. But certain people benefit more. An example is livestock owners, for whom the trees' ability to stay green far into the dry season has a vital appeal. When grasses shrivel away to nothing these trees, whose roots tap into moisture reserves far below the grass's reach, stay green. That is a feature particularly appreciated by anyone facing loss of livelihood when the fodder runs out.

In addition, the living trees are renowned among honey hunters. The flowers attract bees from long distances. Indeed, beekeepers deliberately seek out the trees and hang their hives among the branches. Furthermore, a hollowed-out chocolate-berry trunk makes a most favored beehive.

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[3] There is no collective common name for these fruits. "Chocolate berry" has in the past referred only to *Vitex payos*, but for purposes of this chapter we have co-opted the name to refer collectively to the various African *Vitex* species with promise as fruit trees. It is not a perfect match, given that botanically speaking the fruits are not berries but drupes.

Little is presently known of the nutritional contributions, but the fruits seem likely to be excellent foods. In Sierra Leone they are claimed to cure a condition associated with sores at the corners of the mouth and eyes. That particular condition is most likely a nutritional deficiency caused by lack of vitamins A and B.

Despite the baffling dearth of technical data, these are almost certainly promising resources. Having more chocolate-berry trees would likely benefit Africa's many economies, people, livestock, wildlife, and general environment. Anyone developing sustainable agriculture or raising rural incomes or reducing environmental degradation should consider planting, protecting, and promoting these species.

Clearly, appropriate authorities should engage themselves in the process of moving *Vitex* species into greater production. Specific opportunities to advance these small rugged trees are legion. There are, for example, tasks here for sociologists, anthropologists, village leaders, NGOs of various kinds, government researchers, students, professionals, schoolteachers, and more. Building projects around any of these species might involve:

- Making better use of the local wild plants;
- Documenting traditional usages;
- Selection of elite specimens;
- Horticultural development;
- Plant physiology and botanical studies;
- Food technology;
- Nutrition research and feeding trials;
- Marketing and economic development;
- Publicity and promotion;
- New plantings;
- Financial support for humanitarian or environmental benefit; and
- Coordinating cooperation and education through websites or newsletters.

Although all 70 *Vitex* species might be worth investigating, we highlight below 7 seemingly representative examples.

Black Plum Tallest, most common, and best known of Africa's chocolate berries, this tree (*Vitex doniana* Sweet)[4] produces purple-black fruits that are sweet and mealy. Most of the time they are eaten merely as snacks, but sometimes—notably during the rainy season—they turn into family staples, not to mention profit centers. During that time in Mali—to mention just one country—thousands of women and children go out and collect the fruits to sell in the marketplace. When ripe, the fruits fall from the tree and (because

[4] Synonyms are *Vitex cuneata* and *Vitex cienkowskii*.

Mature *Vitex doniana* tree near Jinka town, South Omo, in southern Ethiopia. (© Erick C. M. Fernandes, ecf3@cornell.edu)

neither the impact nor the soil dampness does any damage) they are usually picked from the ground rather than from the tree.

Black plum grows wild throughout tropical Africa: from Senegal to Angola, including the Congo basin, Sudan, Uganda, and Zambia. It is a much-branched, rounded tree ranging in height from 10 to 25 m. In nature it occurs mostly in coastal savannas, savanna woodlands, and secondary deciduous forests. Though the species is not truly domesticated, throughout West Africa it is found growing in villages. Some of the trees there were deliberately planted, but most were retained when the land was cleared.

Olive-shaped and black when ripe, the fruit has prune-flavored pulp. It can be eaten fresh like plums or dried like prunes. It is also suitable for processing into jams and jellies. A kind of black molasses as well as various

sweetmeats are made as well.[5] The roasted fruit gives a coffee-like beverage.

The fruit, however, is just a beginning of this tree's utility. Indeed, black plum is so useful it has been described as "practically a department store on a trunk." Beyond the sweet-tasting fruits, the young leafy shoots are also popular. They are boiled up and eaten like spinach. The flowers attract so many bees that beekeepers fight over who gets to hang their hives among the branches. The foliage provides fodder for goats, sheep, and cattle. And the tree provides medicines. A bark decoction, for example, is applied to skin diseases and aching teeth, and the leaves are used to treat diarrhea.

To date, little has been done to regenerate this species artificially. However, in preliminary investigations Nigerian researchers have found the black plum propagates easily.[6] It can be planted by direct seeding (preferably after piercing the hard seedcoat so water can pass through). It can be raised in a nursery and transplanted as seedlings, bare-root or potted. And it regenerates naturally by coppice and root suckers, so that vegetative propagation should be readily achievable. This important step, the critical one allowing superior types to be replicated, is probably the key to this species' future as a fruit crop.

Vitex grandiflora Turcz. Much like the black plum, this West African species is common in deciduous and secondary forests from Gabon in the east to Guinea in the west. It is a shrub or sometimes a tree (to 13 m high) with spreading branches. The yellow fruit, about the size and shape of an olive, turns jet black when ripe. Although the pulp is thin, it is made into sweetmeats like those made from the black plum. In Lagos, and probably elsewhere, an alcoholic beverage is made from the fruit. Aficionados liken it to Caribbean rum.

Termite resistant and durable, the wood is valued for making houses, drums, and utensils. It finishes well and has at times been exported to Europe as a top-grade cabinet wood.

Vitex simplicifolia Oliv. A small tree reaching not much more than 5 m, this West African species[7] is common in savanna forests of Ghana, Mali, Togo, and Cameroon, and is to be found as far to the east as Sudan and Egypt. The flowers are greenish and violet. As in related species, the fruit is olive sized, purple-black, and cupped in a calyx like an acorn. The thin pulp clings to the stone, which contains 3 to 4 seeds. The leaves yield an essential oil of such sweet and penetrating fragrance that it is recommended for commercial development.[8]

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[5] In Hausa, these sweets are known as alewa.
[6] Propagation by budding is successful. Information from J.C. Okafor.
[7] This species is also known as *Vitex diversifolia.*
[8] Information from J.C. Okafor.

Vitex payos (Lour.) Merr. These fruits, the "real" chocolate berries, are very popular in parts of southern and eastern Africa, from roughly Mozambique to Tanzania. Zimbabwean villagers are said to collect them in quantity every winter.[9] Each fruit is about 2 cm long, with pointed tips and a chocolate brown or black skin. The juicy pulp surrounds a single hard stone. However, it is definitely an acquired taste. Westerners are typically offended by the flavor, the powdery texture, the oily mouthfeel, and the strong smell. But even then not all is lost: Since 1990, Zimbabwean entrepreneurs have been making jam from the fruit and selling it in the city markets.

The low-growing tree is attractive enough to have promise purely as an ornamental. In full flower it becomes bespangled with myriad flowers, which, set off against the gray of the wood, attract both attention and praise.

This is another *Vitex* that has received some horticultural exploration.[10] Its woody seed has proven reluctant to germinate, but one method for overcoming this natural resistance is leaving seeds out in the open for a year then knick the end where there are two holes. Trees grow slowly during the first three years in the nursery, but then growth speeds up.[11]

Vitex madiensis Oliv. This similar but smaller tree (5-10 m high) occurs from Senegal to Uganda and from Uganda to South Africa. Nowhere, however, is it common. Indeed, everywhere it is rather rare. Most specimens are found in open woodlands. In season, black, egg-shaped fruits dangle from the branches on long stalks. Their smooth and transparent skins enclose a black pulp that is exceptionally popular among all those who know it. The fruits are commonly harvested and sold by women in local and regional market, as are the leaves and roots, which are used in medicine.

Because of the social and economic importance of *Vitex madiensis*, it is considered a top species for local agroforestry. Recent horticultural research to understand the species and identify, select, and reproduce elite types for local growers is showing good results, especially documenting reliable vegetative propagation techniques such as rooting and air-layering.[12] Similar "domestication" research on other *Vitex* species, indeed on "lost" African fruits in general, could quickly advance them from obscurity, and could be accomplished with little expense by horticultural workers across Africa.

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[9] "Around Bulawayo you get *Vitex isotjensis*, *Vitex mombassae and Vitex payos*," writes our contributor Ray Perry. "The last is the best. It is sold in the markets and is among the most popular indigenous fruits."

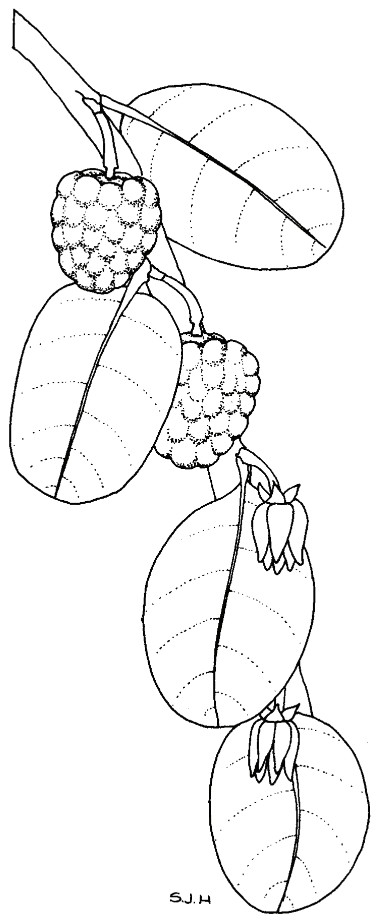
[10] Information from Ray Perry, who adds that care must be taken because the seedlings are easily over-watered.

[11] Information from Ray Perry.

[12] Mapongmetsem, P.M. 2006. Domestication of *Vitex madiensis* in the Adamawa Highlands of Cameroon: phenology and propagation. *Akdeniz Üniversitesi Ziraat Fakültesi Dergisi* 19(2):269-278.

Vitex mombassae Vatke In East and southern Africa, the ripe fruits of this species are picked by the wayside, eaten in homes, and even sold in markets. They are borne in profusion and are eagerly sought. It has been said that Pedi women willingly donate a day's work for permission to gather *mphu* from a farmer's property. The fruits are eaten fresh but are also boiled up into a sweet, black concoction used at least in part for strengthening and flavoring tobacco.

Vitex pooara Corbishley Another southern African species (or perhaps the same as *V. mombassae*), this tree is typically 4-5 m. tall with small, violet-hued flowers. The fruits are 2 cm long, very dark purple or black when ripe, and the calyx may enclose half the fruit. In South Africa's Waterberg region the fruits become so plentiful in season they constitute an important part of the Pedi diet. One drawback is that the juice may stain the mouth; after eating these chocolate berries everyone has black lips.


S.J.H

3

CUSTARD APPLES

The food markets of tropical America routinely exhibit a number of large green premium fruits whose soft and delicious pulp is likened to fruit-salad from a tree. Variously known as "sops" or "custard apples," these attractive greenish globes include soursop (guanabana), sweetsop, custard apple, sugar apple, cherimoya, and bullock's heart. In recent decades these delicacies have been planted ever more widely and certain ones have turned into popular commercial products in locations far beyond their ancestral home, including Europe, the United States, and Australia.

What is not well known is that this famous fruit family (Annonaceae) has African members as well. These, however, are little studied and are not well understood even within their natural habitats. Now they deserve the same kind of attention as their botanical brethren across the Atlantic. One, the African custard apple, has been called "the best indigenous fruit in most parts of tropical Africa." Another, the junglesop, produces probably the biggest fruits in the whole family—as long as a person's forearm and as thick as a person's thigh. A third—perhaps the strangest of all—"hangs like a bunch of sausages," each fruit a bright scarlet link. At least two more produce small tasty fruits that make people's mouths water at just the remembrance from a long-ago childhood. And this group includes a tangy fruit borne on a plant so strange that it barely rises above ground level.

This is a good time to investigate these unusual fruits. Their American relatives, especially the highland cherimoya, are rising in horticultural importance throughout many parts of the world. And crosses between different species are creating hybrids that appear to have their own attractive futures. Clearly, the African counterparts should now join in this march of culinary progress.

Scientifically speaking, Africa's annonas are so neglected that their genetic variability still awaits discovery and description. Fruits of above-average in size and excellent taste exist in abundance. Gathering those should be a priority. Types with few or no seeds are known, and should also be sought. Certain plants also show other useful genetic traits. Some, for instance, grow upright while many others sprawl.

In addition, hybrids between the African species and their American relatives may well produce brightly colored, larger fruits with few (or

perhaps no) seeds. Those are genetic qualities that could bring breakthroughs to both sides of the Atlantic.

However, much remains to be learned before anyone can cultivate the African species with confidence. At present, for example, many of the seeds are reluctant to germinate.[1] And some of these species–junglesop is an example–take as long as 10 years to produce their first flowers. Vegetative propagation is apparently untried, but experiments along this line seem likely to overcome the delay as well as several other practical difficulties.

All in all, then, these inter-related species comprise a great group for Africa-wide collaborations and for both professional and amateur contributions. As with other pre-domesticated species, urgent needs are:

- Making better use of the existing wild resource;
- Documenting traditional and modern usages;
- Collecting different species and types for comparative testing;
- Genetic selection; and
- Horticultural development.

Philanthropists could help a lot. Funding any of these steps would immensely speed up the process of bringing these crops to modern life. Progress and satisfaction will not even be notably expensive.

Notable interesting delights among local custard apples are described below.

AFRICAN CUSTARD APPLE

Best known among the indigenous annonas, African custard apple (*Annona senegalensis*)[2] produces fruits that smell like pineapple and taste like apricot. Found from Senegal to South Africa, the tree is a surprisingly common companion to thousands of villages. People everywhere go out of their way to preserve a few trees around their houses or in the fields where the crops grow. But for all that, this species has never been awarded serious agronomic attention.

If now given horticultural help, the African custard apple will likely become planted quite intensively and its fruits will become better foodstuffs, far more widely eaten and far more widely sold in local and city markets than they are today. As a result, the crop would contribute substantially to Africa's future nutrition, not to mention its overall rural economy.

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[1] "Despite many attempts," write our contributors Roy Danforth and Paul Noren, "we have been unable to germinate *Annona senegalensis* seeds except about two plants out of thousands of seeds."

[2] This plant's botanic name is in dispute. The full formal name is *Annona senegalensis* Auct. Another name often cited, but apparently in error, is *Annona senegalensis* Pers. Some taxonomists denote the plant as *Annona chrysophylla* Boj.

The African custard apple tree is a surprisingly common companion to thousands of villages from Senegal to South Africa. Resembling its more famous American cousins, the fruits smell like pineapple and taste like apricot. (Paul Latham)

In its present unselected state, this local custard apple is smaller than its American counterpart. Also, its pulp is packed with many pale brown seeds. Despite that, however, ripe ones are very attractive with bright colors and tasty flesh. In appearance, these fruits are lumpy skinned, roughly spherical, yellow to orange in color, and fleshily soft to the touch. They are best picked before achieving full ripeness and stored in a warm, dark place to ripen slowly out of reach of the sun.

The tree bearing these fruits branches so prodigiously it is usually hardly more than a shrub. Under exceptionally favorable conditions it may reach 8 m, but more often is only 3 m tall. It has large leaves and is deciduous. Although distributed throughout tropical Africa (Senegal, Congo, Sudan, Kenya, Zambia, Malawi, Zimbabwe, and Mozambique, for example), it clearly possesses at least modest cold tolerance. It occurs, for instance, in subtropical parts of South Africa, reaching its southern natural limit on Natal's north coast.

Ecologically, the plant appears best suited to warm-but-not-hot conditions, as well as to fairly moist environments (probably those where annual rainfall exceeds 750 mm). In nature it tends to occur in mixed woodlands and open savannas. It also seems to favor sandy sites; indeed, in the wild, it is commonly found on deep sands. However, it also readily colonizes rocky outcrops.

In addition to its own promise, the species may also benefit its better-known American relatives in at least two ways. For one, smaller seeds could

perhaps be induced in the popular cherimoya or soursop through creating hybrids from them using the African custard apple as a pollinator (it produces pollen prodigiously). The African custard apple may also make an excellent rootstock for its relatives. The fact that it likes deep sandy soils suggests that its roots plunge deep and downward, a feature of special significance in conferring drought resistance.

The plant has seldom been tested outside Africa, but there is a reference to it growing in Brazil. According to this report, it has become well established especially around Minas Gerais, Bahia, and Espirito Santo.[3]

Beyond its fruits, African custard apple could have other important local uses. Various parts of the tree are renowned for providing medicines. In Swaziland, for instance, the bark is used to treat open sores.[4] And there may be merit in using the leaves against lice and other skin pests because other members of this genus are known for their lethal effects on insects.

JUNGLESOP

The junglesop (*Anonidium mannii* (Oliv.) Engl. & Diels)[5] is a medium sized tropical African tree bearing the fruits that are almost as long as a person's forearm and as thick as a leg. Typically these giants weigh between 4 and 6 kg; they are often as big as jackfruit (the world's biggest fruit). Despite being more than half a meter long, most of those seen today are not fully rounded out because of inadequate pollination.

Although a rarity, the plant is very popular where it occurs. In the Central African Republic, for instance, people reportedly pay up to two days salary for a single junglesop. And special trips are organized to collect the fruits during the season.

This fruit's tough and leathery brown skin has a surface patterned with raised diamond-shapes. About four or five days after picking, the fruit softens and can be easily broken open to expose the soft, yellow-orange flesh inside. In some varieties this is deliciously sweet and very good to the taste; in others, it can be not only sour but downright awful. Just how mature the fruit was when picked can affect the sweetness, but genetics also plays a part, and locals know individual trees that are always sweet and others that are always sour.

As in most annonaceous fruits, the flavor is rich—but in this case it is sometimes so rich that a person cannot eat more than a few bites at a time. But apparently not everyone is so inhibited: People in northern Congo, for

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[3] Cruz, G. L. 1979. *Dicionario das Plantas Uteis do Brasil*. Editora Civilizacao Brasileira S.A., Rio de Janeiro. The plant is locally known as araticum da areia. The fruit is described with a rougher surface and much bigger than in Africa; it may be an elite germline but could also be a hybrid or even a variation of some other *Annona* species.

[4] Information from Harry van den Burg.

[5] Previously known as *Annona mannii*. Information in this section came especially from Roy Danforth and Paul Noren.

Bangui, Central African Republic. In this area, custard apple trees are a common accompaniment to rural houses. They are beloved for the deep shade they provide as well as for the quality fruits that are tasty and salable in the market. (Roy Danforth and Paul Noren)

instance, say that five hungry men can completely fill their stomachs with a good-sized junglesop!

Although (or perhaps because) this is a common tree in some of the Central African rainforest, people have so far failed to develop it as a crop. Attempt after attempt has come to nothing. Part of the difficulty lies in fungal diseases that attack the plants. Today, these problems can probably be

overcome by careful selection of growing site and perhaps other techniques such as grafting onto resistant rootstocks or the judicious use of fungicides.

Although essentially unknown outside Central Africa, individual trees now can be found in southern Florida, Hawaii, Malaysia, and northern Queensland (Australia). All are young, but each is growing well. This indicates possibilities for a better international understanding of the species, its management, and its fruit.

GROUND SOP

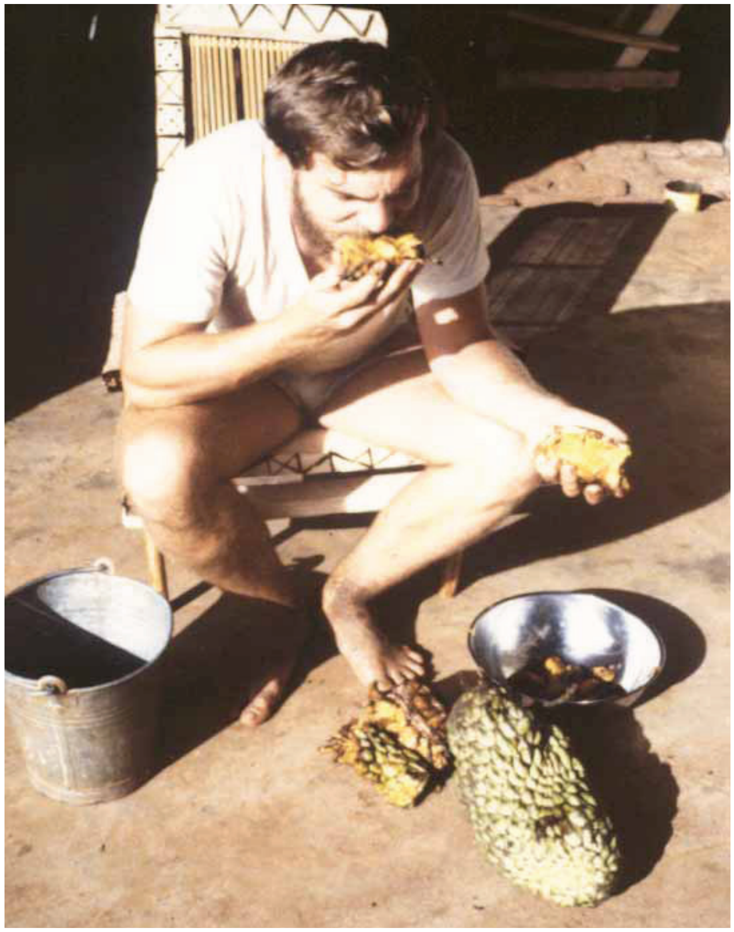
This plant (*Annona stenophylla* Engl. & Diels) is a dwarf of the family. Indeed, it is so small it bears its fruits literally "on the ground." Nonetheless, those low-borne fruits rank high in people's esteem. They are said to be better eating than even the African custard apple. A southern Africa native, it is found in northern Botswana, northern Namibia, Zimbabwe, and Mozambique. Despite the plant's diminutive size, the fruits are large. They are yellow or reddish orbs crammed with pumpkin-colored flesh. They are said to be tasty, and people eat them raw, cooked, or preserved. In the diets of those living in the semi-arid northern areas of Botswana and Namibia, ground sop becomes almost a staple during the season.

OTHER SPECIES

Other African Annonaceae yield edible fruit delights as well. Nothing much can be said about them because as of now they are among the most obscure resources in the world. Essentially nothing has been contributed to the scientific literature describing their qualities and promise. Despite that neglect, however, these seem to have qualities that make them worth exploration and perhaps exploitation. They include the following species.

Baboon's Breakfast This plant (*Hexalobus monopetalus* (A.Rich.) Engl. & Diels)[6] is a shrub or small deciduous tree (2-8 m tall) found throughout tropical Africa—as far north as Senegal and Sudan and as far south as Gauteng in South Africa. Its small, oblong fruits are scarlet when ripe and sometimes are patterned with green-veins. Inside is a juicy white pulp that is eaten fresh or in the form of jam (said to be delicious). Fresh, they have a pleasantly acid taste. The seeds are sometimes separated, dried, and employed as a spicy condiment. The cluster of oval scarlet to orange fruitlets, each about 5 cm long, are borne in a single flower. According to one report they taste like the red, sweet 'Satsuma' plum, and are much sought by local people, not to mention myriad animals. In nature, the plant grows in open woodlands in dry regions as well as reasonably well-watered ones. It therefore seems quite adaptable.

[6] It is known as shakama plum (from the Shangaan name in South Africa) and, in Zambia, as mkandachembele (N); Bambara names include sama-bolokoni (elephant's little toe).



Junglesop produces probably one of the world's biggest fruits—as long as a person's forearm and as thick as a person's thigh. Like America's custard apples, especially cherimoya, this one is sweet and soft. Clearly, this and the other African custard apples should now join this culinary wave that is lifting other custard apples in horticultural importance in several parts of the world. (Roy Danforth and Paul Noren)

Elsewhere in tropical Africa are found the botanically related *Hexalobus senegalensis* A. DC (a savanna species) and *Hexalobus crispifloris* A. DC (a forest species). Both also offer good fruits, and people like having the trees around. The latter species is abundant in Cameroon cocoa plantations, "undoubtedly the result of effective conservation, enrichment planting or other type of human intervention," notes an FAO report.[7]

[7] van Dijk, J.F.W. 1999. An assessment of non-wood forest product resources for the

Dwaba-Berry The dwaba-berry (*Monanthotaxis caffra* [Sond.] Verdc.) is a climber, shrub, or small tree (up to 3 m) that occurs in evergreen forests and nondescript scrub in eastern South Africa, Lesotho, Swaziland, and Mozambique. Its small, flask-shaped fruits come in clusters. Yellow at first, they ripen to a very bright red. Most are eaten fresh and have a slightly acidulous flavor. Among the wild fruits of northern KwaZulu (South Africa), these are a favorite of the summer. In Swaziland, fibers stripped from the bark are made into baskets or even woven into a cloth (traditionally used for burial shrouds).

Monkey Fingers The so-called Monkey fingers (*Friesodielsia obovata* [Benth.] Verdc.)[8] is the fascinating fruit that "hangs like a bunch of sausages" from a single flower of a small tree. The individual fruitlet fingers are bright scarlet, fleshy, and tart. They are eaten fresh or stewed or cooked as a tasty jelly. Some are fermented into wine. A fruit of such strange shape and such bright color seems likely to create great interest in the modern upscale marketplace, whatever it tastes like.

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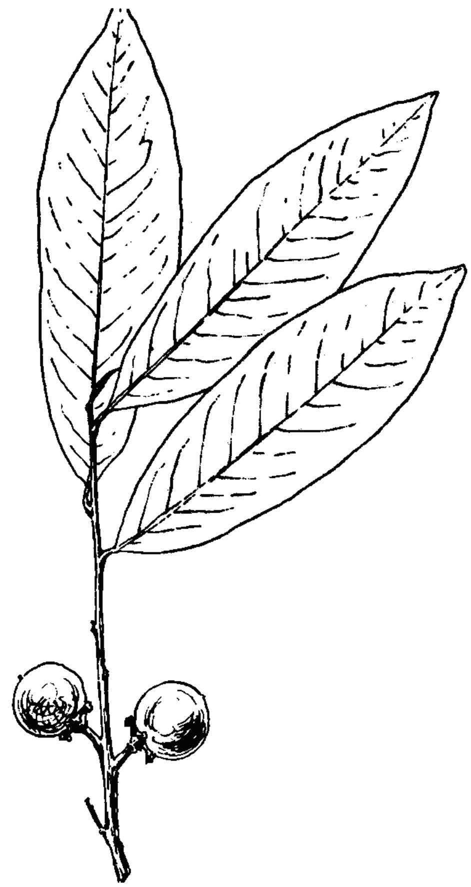
development of sustainable commercial extraction. In T.C.H. Sunderland, L.E. Clark, and P. Vantomme, eds., *Current Research Issues and Prospects for Conservation and Development*. Food and Agriculture Organization of the United Nations, Rome.

[8] A synonym is *Popowia obovata* (Benth.) Engl. & Diels.



Diospyros mespiliformis

4

EBONY

Ebony trees (*Diospyros* species, Ebenaceae) are renowned worldwide. Their black, rock-hard wood is perhaps the smoothest, shiniest, and most beautiful of all. It is almost a precious material, sometimes sold by the gram like gold. But *Diospyros*, the generic name for these plants, actually means "fruit of the gods," and outside the tropics ebony species are renowned for the persimmon. Originally from China, persimmon (*Diospyros kaki*) has for centuries ranked among the most prized fruits in certain areas, notably Japan and parts of Europe. Now it is gaining a more extensive following, with commercial production rising in the United States, Europe, Israel, and elsewhere. Thanks to genetic selection, airfreight, and advanced materials, an international trade in this fragile fruit is now beginning, with Israeli persimmons flying first-class all the way to Europe and the United States.

Almost unappreciated at present is the fact that most species in this genus are tropical, and that the species of Africa, Southeast Asia, and the Americas also bear fruits. Typically, those fruits are yellow, red, or purplish in color, about the size of golf balls, sweet and tasty, exceptionally abundant, and widely enjoyed. Examples include the black sapote (*Diospyros ebenaster*) of Mexico and the velvet apple (*Diospyros discolor*) of the Far East.

Although hardly anything is known about Africa's ebonies as crops, their long-term prospects could be good. These counterparts of the persimmon seem adaptable species; occurring from dry to humid zones all across the continent, from Senegal to Sudan and from Sudan to South Africa. This suggests that various ones could in the future be grown more widely too, and not only as scattered village trees but also as densely planted stands.

For agroforestry projects, African *Diospyros* species could be especially valuable. They are trees people know and love. As long as planting materials of superior types are supplied, millions are likely to plant them spontaneously and protect them from harm. Even now, volunteer plants are well cared for.[1] Indeed, these African ebonies could become valuable not only for individual plantings but also for bordering streets and highways, for fencelines, for village plots, and for small-scale entrepreneurial endeavors (care should be taken when introducing ebonies to new areas, however, as

[1] This is true of *D. mespiliformis* in Namibia, for instance. Information from P. du Plessis.

Jackal berry tree, Kruger National Park, South Africa. The best known and most developed ebony-fruit species, the jackal berry (*Diospyros mespiliformis*) is typical of the group. Its black, rock-hard heartwood is used for carvings, but locally it is more renowned for its fruits, a popular favorite. (Willem van der Merwe)

some species may be invasive of open ground.). In certain areas ebony forests might be established as food reserves, which would likely be an excellent way to obtain local cooperation for planting and protecting both trees and land. In the long run, however, the very valuable wood could be the greater financial prize.

Despite their domicile in the wild, African persimmons are particularly enjoyed. For marketing on a large scale, they are suitably sized, attractive to look at, and appealingly sweet and succulent. They are, however, very soft and delicate. And this fragility is at present the biggest—perhaps only—thing limiting their advancement into big time food resources.[2]

These fruits are versatile. Most are eaten fresh. Many are eaten dried. Some are pulped and incorporated into sauces. A few are reduced to concentrate, sometimes sold in frozen form. Others are incorporated into

[2] "They are virtually impossible to transport fresh," wrote one of our contributors, "but they dry very well."

porridges, toffees (called ma'di in Hausa), fermented drinks, and even a distilled liquor, "ebony brandy."

They also help save lives. People keep the dried fruits as a reserve for use following the end of the farming season, a period when food often runs out. But even then ebony is much more than a famine food. Africans often consider this local version of dried apricot much better than the real thing.

As far as nutrition is concerned, little is known with certainty. The fruit pulp consists largely of water and carbohydrates, with small quantities of minerals for good measure. Details of the vitamin content are so far unreported, but the pulp can be expected to be a source of vitamin C, with perhaps 25-50 mg per 100 grams. Interestingly, like apples, commercial persimmons have more vitamin C in their skin than in their flesh. That skin can have more than four times the already substantial amount it encloses. In addition, the skin's bright red color likely reflects the presence of lycopene, a nutritionally important carotenoid found in tomatoes.

Fruit pulp is not the only useful resource these trees confer. Others are:

Seeds Seeds are said to be edible, but this seems to depend on species, and does not apply, for instance, to *Diospyros mesipiliformis*.[3]

Foliage The leaves are used as animal feed.

Bark In some species a bark infusion yields a dark blue dye for coloring cloth. Also, the injured bark exudes a gum, useful as glue.

Wood The world famous fine-grained black or dark-brown heartwood is used in cabinetwork and carving. Because of its termite resistance, it has long been employed for posts in house construction. More valuable personal uses include tool handles, pestles and mortars, and small dugout canoes. Most valuable of all is ebony's use in sculpture and crafts, for which it sells by the gram. In the past, some was burned for firewood and charcoal, a phenomenon now almost unthinkable.

PROSPECTS

These plants are quite versatile and adaptable. The limitations on ebony-fruit enterprises lie mostly with the softness of the fruit. Just which zones within Africa are best for ebony-fruit enterprises is today a guess. Possibilities are:

[3] According to contributor Harry van den Burg, the roasted seeds of *Diospyros whyteana* make a surprisingly good substitute for coffee.

African ebony fruits under development as an orchard crop in Israel. These persimmon counterparts could in future be widely grown both as scattered village trees and also as densely planted stands. Although hardly anything is known about Africa's ebonies under cultivation, their long-term prospects as fruit-and-timber resources could be good. The sale of fruits would support the annual maintenance costs and perhaps provide income during the long years in which they are laying down their heartwood, which is so prized by artists it can be sold to the world in small select pieces. (Yosef Mizrahi)

Humid Areas Excellent prospects. Because most African ebonies hale from the humid lowlands, hot and steamy sites they would seem to offer excellent prospects, perhaps even in sizeable plantations. Also possible is the concept of "salvation farming," in which threatened native forests would be endowed with economic value by organized harvests of sustainable forest products, including ebony fruits. The importance of this lies in the fact that forests producing food and income have a better chance of being spared the match, machete, or chainsaw.

Dry Areas Modest prospects. Clearly, Africa's most desiccated zone will never be prime ebony fruit country, but the Israeli experience indicates that good production might be achieved in certain dry areas, especially if a little irrigation can be found. Forestry and agroforestry projects throughout the savanna region should consider incorporating at least a few of these trees into their testing programs.

Upland Areas Doubtful prospects. The potential for Africa's ebony fruits for Africa's highlands is untested. It will depend on species, latitude, and altitude, as well as site orientation and consequent exposure to cold. At the very high zones of Ethiopia, for instance, potential is likely to be zero. But at lesser elevations across the continental uplands, it could well be excellent.

NEXT STEPS

Now is the time to reconsider these species. Given horticultural selection, ebony fruits may prove just as appealing to tropical Africa as the persimmon is to the temperate world. Foresters, pomologists, and interested plantsmen and plantswomen throughout Africa could probably develop the native persimmons into important crops without massive expenditures or major governmental interventions. But to achieve any sweeping success will take teamwork among persons with differing skills.

For one thing, plant-nursery workers and others skilled in propagating plants are urgently needed. Vegetative propagation has not yet been reported, but is probably not difficult to accomplish. In the wild, the trees regenerate by coppice and root suckers as well as by seed. Older seed has a built-in dormancy, but that is easily overcome with hot water treatment. Although seedlings grow slowly at first, they later elongate rapidly. Apparently, they can be transplanted into forest clearings, but, due to their slow early growth, need a lot of weeding.

Foresters could also contribute. Ebony is not only ranked among the world's finest woods, it is also already often associated with Africa and Africans. So far, however, there have been few, if any, attempts to produce it in plantations. Largely, this is owing to the trees' perceived slow growth and the expectation of a financially devastating delay between planting and harvesting. But all this may change if annual crops of valuable fruits can be harvested during the years the trees are maturing to timber size. With some testing—as well as with some cleverness or luck in selecting compatible sites and planting materials—these plants could well prove faster maturing than is now anticipated. Indeed, evidence suggests that this might be true even now. *Diospyros lycioides*, for instance, is an ebony bush bearing heavy crops of pleasant fruit that grows fast.[4]

The skills of food scientists are also needed. Harvesting and handling these fragile fruits is an especially uncertain topic. In general, the trees flower in the rainy season and ripen their fruits in the dry season. In humid lowland forests fruits ripen about 6-8 months after flower fertilization, but in hot, dry woodlands they ripen much faster. Although the ripe fruits are usually collected from the ground, they may be picked from the tree.

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[4] In Swaziland the rate under good conditions is half a meter a year or more. Information from Harry van den Burg.

Anthropologists and others interested in traditional cultures could do much to help. The different species, different traditions, and different experiences with these fruits in various parts of Africa are uncollated. Someone should pull together a corpus of continent-wide knowledge. Important insights into the propagation, horticulture, harvesting, handling, and processing of the different species will be gleaned from such work.

Non-specialists can help as well. One necessary step is to gather germplasm in the different and varied regions where the ebony fruits grow, a task perhaps best done by those residing in the remote rural regions. Another interesting approach is to convene contests for the biggest, sweetest ebony fruits. People who are observant and adventurous are likely to respond eagerly. Thus, there are likely to be many budding winners, whose germplasm could be of benefit to all Africa.

Although individuals throughout Africa need to contribute their time and talents to the selection, propagation, and other studies of the ebony fruits, the development of these crops could also be a good topic for voluntary and economic-development assistance from Japan. Its experts and expertise on the horticultural development of Japanese persimmon might well provide a key to quickly achieving the potential inherent in Africa's own counterparts.

However, horticultural improvements will not occur overnight and much scientific groundwork remains to be done. All in all, there's much to learn about means for maximizing these plants fruit production. Examples follow.

Fruit Quality One prime task is improving fruit quality, especially the strength of the skin. This is vital for making African persimmons suitable for mass markets. Superior types already exist, but they are scattered throughout the continent and their whereabouts is unrecorded. They need to be located and vegetatively propagated. Disseminating planting materials (such as scion wood) of these will give the crop a chance in exploratory production and perhaps even commercial-scale ventures. Overall fruit-quality features to consider include hardness, shape, size, color, general appearance, skin thickness, skin strength, pulp-to-seed ratio, and tannin levels.

Fruit size is a straightforward target for selection. Today's African ebony fruits are much smaller than a persimmon, but larger-fruited forms undoubtedly exist. These should be plucked from hiding. Fruit-size might also be increased by horticultural or genetic manipulation or by improved management of the trees.

Tannins need to be considered, too. It may seem likely that the immature African persimmons, like those in the rest of the world, will pucker the mouth. But those of the main African species are commonly tasty even unripe. Nonetheless, any chance trees with especially low-tannin fruits should be seized upon.

Genetic Manipulation Hybridization between African species might produce larger (maybe even seedless) fruits. Also, hybridization with the common persimmon might perhaps lead to the betterment of both.

Management Yields at present are low, but this is undoubtedly through lack of horticultural help. Attention should be given to the plants' needs for water, fertilizer, and pest and disease control. Grafting onto rootstock of the same or different species also needs testing, particularly because it might produce dwarf plants that would be easier to manage as food producers.

Handling Chilling requirements for maximum storage, shelf life under ambient conditions, and overall quality control all need determining.

Nutrition The nutritional composition and tannin contents of the various species and major genotypes should be assessed.

Processing Processing is important with these fruits, which are often too soft and squishy to transport, especially in hot weather. Opportunities exist for manufacturing dried and preserved products as well as beverages and prepared foods, including porridges and toffees flavored with ebony fruit.

Marketing Much can be done to better market fruits to consumers in African cities; many will be as new to ebony fruits as Europeans or Asians.

Which of the numerous ebony-fruit species to advance is as yet uncertain. Below some possibilities are highlighted.

JACKAL BERRY TREE

The best known and most developed ebony-fruit species in Africa, the jackal berry tree (*Diospyros mespiliformis* Hochst ex A. DC) is also typical.[5] An evergreen or semi-evergreen, it reaches 15-20 m tall in drier zones and up to 45 m in humid forests. Mature specimens have dense, wide-spreading, rounded crowns with trunks that are sometimes buttressed or fluted. However, in some regions the plant occurs only as a large, multi-stemmed shrub. It is common in the gallery forests alongside rivers in southern Africa. According to at least one observer, these forests constituted one of the major habitats in which humans evolved. This fruit, therefore, is likely to be one of our oldest foods of all.

Male and female flowers appear on different trees: males in clusters; females solitary. The fruits are more or less round, up to 3 cm in diameter, greenish and hairy when young, yellow or purplish and smooth when ripe.

[5] Vernacular names are abundant, including mu-koro (Kikuyu) and gughan (Arabic), eenyandi (Oshiwambo), and ngombe.

The pulp of these small fruits is *very* sweet. This is one that is quite tasty even when not completely ripe—it seems remarkably tannin-free for a persimmon. The 4-6 dark brown seeds are oblong, flattish, minutely warty, and hairy.

As for known environmental requirements, they can be summarized as:

Rainfall The tree is generally found in areas receiving from 500-1,270 mm in four out of five years, but grows also in areas with around 300 mm (Chad and Namibia, for instance).

Altitude It grows naturally up to 1,250 m (in Tanzania, for instance).

Temperature In areas with mean annual minimum temperature of 16°C. Seems to grow best in areas with mean annual maximum temperature of 27°C.

Soil The species appears to favor heavy soils, but is not unhappy in sands, loams, volcanic soils, or rocky sands with clay or alluvium.

OTHERS

Yet more ebonies bearing heavy crops of pleasant fruits include the following from southern Africa (often called "blue bushes" in the region):

Diospyros lycioides Desf. This small shrub of central and southern Africa bears reddish or yellow fruit the size of small plums. The pulp is translucent and faintly sweet.[6] This is the species that grows fast. In Zimbabwe it produces fruit after 4 years, while still in the nursery.[7] Moreover, its wood is high in quality. Twigs from this species are commonly used as a toothbrush and have been found to contain effective antibacterial compounds.[8]

Diospyros kirkii Hiern In spring this small tree of the tropical lowveld of southern Africa bears sweet mealy fruit (2.5-4 cm in diameter). The fruits are good enough eating and the trees are resilient and productive enough that one writer, after surveying hundreds of wild food plants, considered this species as "perhaps being worth domesticating."

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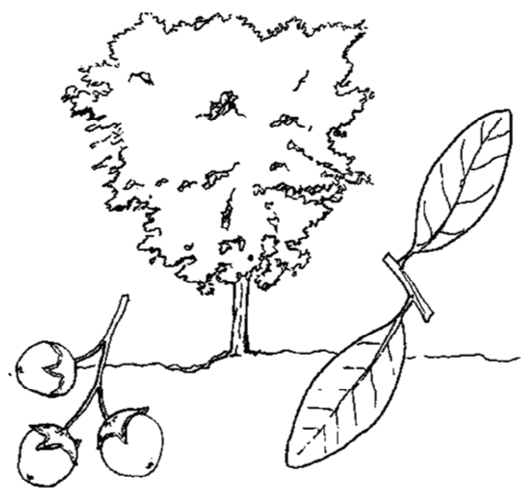
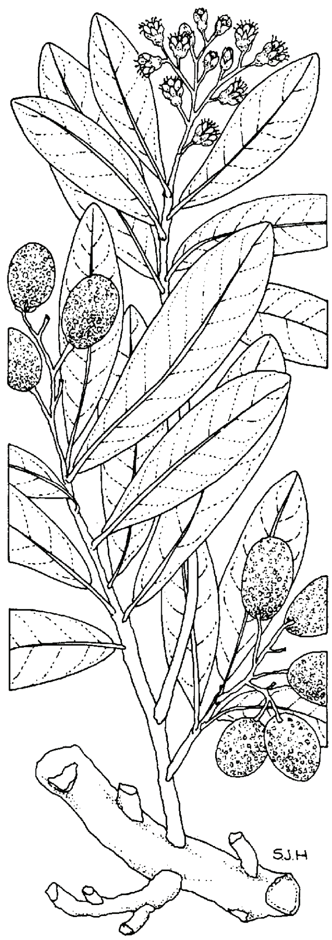
[6] "This is a nice fruit," wrote our contributor Harry van den Burg. "It has three subspecies [here] in Swaziland, and lots of genetic variability that is worth exploring."
[7] Information from Ray Perry.
[8] Cai L., G.X. Wei, P. van der Bijl, and C.D. Wu. 2000. Namibian chewing stick, *Diospyros lycioides*, contains antibacterial compounds against oral pathogens. *J. Agric Food Chem*. 48(3):909-914.

Diospyros batocana Hiern Not all African persimmons are small—this one is apple sized. Those yellowish-orange fruits have a very acid pulp that is said to be refreshing on a hot day.

Diospyros chamaethamnus Dinter ex Mildbr. The inhabitants of Namibia and Botswana (especially San and Okavangos) regard this as one of their most important foods. They say "a man could live on these fruits alone for three months, provided that water was available." The gelatinous flesh is commonly pulped in water and drunk as a sweet, milky beverage.

Diospyros pallens Thunb. Southern Africa. According to one account, local fans can eat at one sitting as much as a kilo or two of these red fruits, which when fully ripe taste like raspberries.





Parinari capensis subsp. *capensis*

5

GINGERBREAD PLUMS

Within the vast stretch of territory between Senegal and Madagascar there exist a number of interrelated wild fruits (*Parinari* or kindred genera) with very agreeable strawberry-like flavors. Usually red or yellow in color, these plum-sized delicacies lack the sourness typical of wild fruits (and of plums for that matter). These so-called gingerbread plums can have a texture firm enough to crunch like a crisp apple.[1] Those who love the crunchy sugariness, especially children, consume them in large quantity.

These seem like fruits with a future. They do not bruise easily. Their colorful skins and bright yellow flesh appeal to the eye. Their sweetness appeals to the taste buds. All in all, millions of Africans like them a lot. Indeed, during the harvest season certain peoples rely on gingerbread plums almost as a dietary staple.

These fruits are used in a variety of ways. Many are eaten fresh or are boiled with cereal. Pounded with water, they create a colorful red counterpart to lemonades or orange crushes. And often this refreshing liquid is thickened with flour (from maize or cassava) and boiled into a widely enjoyed and tangy tasting gruel. Fragrant syrups are often prepared as well, and gingerbread plum is also the basis for some drinks that prove much stronger than any fruit squash.

With most of these botanically interrelated fruits, the kernels inside the seeds are eaten too. These somewhat oily "gingerbread nuts" are usually roasted and enjoyed like cashews or almonds. Some are consumed as snacks, others mixed into cooked dishes, and a few are pressed to yield cooking oil.

Beyond food, these trees provide a fairly hard wood that polishes to a bright luster and ends up in prized furniture, not to mention building materials, firewood, and charcoal.

No one has ever attempted to develop the various gingerbread plums into modern and reliable resources, not even to gather together representative

[1] Traditionally, the name gingerbread plum has been applied to a couple of these species (especially *Parinari excelsa* and *Neocarya macrophylla*, see below). We recommend extending that usage as a collective name for all the various *Parinari* and related species with edible fruits. This is not without hesitation: these African delights are far from being soft and watery, and botanically they are only very distant cousins of plums.

Fruits of the "mobola" gingerbread plum are reddish-yellow mottled with gray. They are sweet, delicious, and popular, especially in Malawi, where they are regarded as one of its best wild foods. Trees yield exceptional quantities of fruits, with most eaten out of hand. (PhytoTrade Africa)

specimens for comparative study, grafting, or hybridization. For all that, though, several are already managed in a way that could be called "semi-cultivated." In other words, farmers spare the trees whenever they clear land and subsequently support the rescued specimens to a greater or lesser extent.

Producing vastly more of these tasty fruits under more organized conditions seems eminently feasible. Seeds are difficult to germinate, but most (perhaps all) *Parinari* species are easily reproduced via root suckers. Whenever exposed or wounded, the roots erupt in a profusion of sprouts, which can be cut off, rooted in sand (preferably under intermittent mist), and used to directly establish new plantings. Root cuttings also provide a key to propagating elite specimens. Through them, superior types could be quickly and easily established across much of Africa: clustered in villages perhaps, or scattered alongside roads in the valleys and tracks in the hillsides.

The following species seem particularly worthy of investigation, intense selection, and efforts at domestication.

MOBOLA

The best known of these fruits, mobola (*Parinari curatellifolia*)[2] is found in woodlands and tree savannas throughout tropical and southern Africa. It occurs extensively, for example, in Zambia, Zimbabwe, and the lowveld of South Africa. The trees yield exceptional quantities of reddish-yellow fruits, mottled with gray. They are sweet, delicious, and popular. Malawi regards them as one of its best wild foods. Most are eaten out of hand, but some are concentrated into a syrup that is poured on cereal products (the way maple syrup is in North America). Beer is also brewed, and the unripe fruits are converted into a sweet, very pleasant, non-intoxicating beverage (called luzwazhi in Zambia).

In various places the seed kernels are also eaten. These so-called mobola nuts are rich in oil and are considered excellent almond substitutes. They are eaten raw or are added to vegetables, fish, or soups during cooking.

Although the tree grows and matures slowly it is so highly prized that it could have a future as a plantation crop.[3] The combination of a tasty fruit and an easily stored nut provides a double attraction for domestication. Although analyses have yet to be done, it seems probable that the nut has considerable nutritional value.

The tree—sometimes known as the "hissing tree" because of the final sibilant groan it makes when chopped down—is almost evergreen and can be as tall as 20 m. This briefly deciduous species has an erect stem, a dense spreading crown, and branches that droop all around. At certain times of the year, but particularly in hot weather, it can emit an unpleasant odor.

The wood is light brown, hard, and borer-proof. While not durable if exposed to weather, it is used for simple building purposes such as poles for huts and sheds. It is also made into mortars for pounding grain. Unfortunately, it contains silica crystals that blunt saws and other cutting tools. Despite being considered a prize source charcoal, mobola is seldom felled for fuel.

These beautiful trees are conspicuous across the landscape of southern Africa and it is easy to understand why one of them was chosen to bear a final tribute to David Livingstone. After his death (on 4 May 1873) his helpers carved a commemorative inscription on the trunk of a fine mobola marking the spot at Chitambo's village in central Zambia where the famous explorer died.

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[2] *Parinari curatellifolia* Planchon ex Benth. (including *P. c. mobola* (Oliv.) R. Grah.), sometimes called mobola plum.

[3] One contributor wrote saying, "In my opinion this is the southern African fruit with the greatest potential for domestication. Currently, however, efforts are directed at marula, which I think is inferior in taste and has less yielding capacity."

SAND APPLE

The sand apple (*Parinari capensis* Harv.) is one of earth's strangest plants: a shrub that grows underground.[4] In a sense, it can be considered a tree without a trunk: branches pop up directly from the roots. These "root branches" are very short, extending less than a meter above ground.

Found widely scattered over the southern half of Africa,[5] its weird shrunken tree bears hard, brown fruits about the size of small plums. Even when ripe they are somewhat dry, smelly, and astringent, but to those who know how to handle them they are delicious. The key is to bury them in the sand (hence the name), a process that, during the course of a few days, removes the astringency, hardness, and odor.

Despite its bizarre growth form (or perhaps because of it), the sand apple is highly tolerant of harshness and often grows where other crops prove unreliable. It is, for instance, common on the sandy palm veld of coastal northern Natal, where the watertable fluctuates wildly from one to two meters below the soil surface. Despite that ability to deal with drought, the plant is also found on the edges of marshes and beside seasonally waterlogged depressions.

People in various locations—in the northern Kalahari and Zambia's Barotseland, for instance—eat both the sweet outer flesh and the raw kernel. They also ferment the fruit into alcoholic drinks.

Of the nutritional value nothing is presently known, but it must be quite substantial. Sand apples reportedly can sustain a person, keeping them in reasonable health for about 3 months without any other kind of food. The fruits can also be dried and formed into a soft "cake" that keeps so well it can be safely saved emergency use. David Livingstone often carried dried sand apples, and on one of his travels relied on them as his only food for more than 60 km of hard walking.

ROUGH-SKINNED PLUM

Another of these interrelated species, the rough-skinned plum (*Parinari excelsa* Sabine) is also commonly called gingerbread plum.[6] It is found throughout both East and West Africa, and is well known, for instance, in both Tanzania and Gambia. It comes in two forms: One, a large tree (as much as 50 m tall) of the moist forest; the other, a smaller tree of open (often riverine) woodlands.

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[4] This strange form of plant has been called "geoxylic suffrutex," a term southern African botanists use for a "tree" with no trunk between root and branch. The colonies are presumably clonal; the mainly underground stems are rhizomatous.

[5] The plant is best known in Swaziland, South Africa, Namibia, and Botswana. However, it also extends northwards as far as Congo and Tanzania. Two subspecies, *capensis* Harv. and *incohata* F. White, have been designated.

[6] Also known as kura (Fula), mampato (Mandinka), bulee (Jola), and other names.

The fruits are red or tan in color and are not unlike small plums, but with rough, pitted, and sometimes-silvery skins flecked with brownish to purplish patches. Each contains yellowish flesh enclosing a hard pit.

On ripening, the fruits quickly fall. In wet weather they quickly perish on the ground, but in dry weather they remain in good condition for a week or so. Used as both a snack and a staple, the ripe flesh has a flavor some liken to caramel, others to avocado. The different descriptions perhaps reflect genetic variability, because yet others have written that the fruits are "astringent to sweet, depending on the individual tree." It is also written that they are much sought by small boys (so they can't be all bad).

Like the mobola, the rough-skinned plum is at times an important emergency food. It is also employed more mundanely in everyday items such as beverages. For this, the pulp is soaked in water and the resulting sweet liquid filtered off and drunk directly. Sometimes the diluted juice is first concentrated by boiling and at other times it is fermented into intoxicating liquor.

An important timber, this species' wood is hard and durable and in some areas is sought for cabinetry, joinery, construction, and furniture. It also makes excellent firewood.

In essence, little has been done to regenerate this species artificially. Perhaps that's because of recalcitrant seeds. Research carried out in Tanzania showed that only a few of the seeds are viable. Actually the researchers, who were at the Lushoto Silviculture Nursery, had a hard time finding any seeds…people and animals gobble the fruits up too quickly for mere scientists. Regeneration by wounding the roots and planting the resulting suckers was judged the more promising propagation method.

GINGERBREAD PLUM

A purely West African species (formerly *Parinari macrophylla* Sabine; now *Neocarya macrophylla* (Sabine) Prance) is another member of this interesting group.[7] Its mealy fruits are especially loved in Sierra Leone, but are esteemed from Senegal to northern Nigeria, where they can be seen in the local markets. The flesh is soft and yellowish when fresh, with a peculiar flavor sometimes likened to avocado.

As with the other species, the plant is semi-cultivated, and its abundant fruits are normally harvested from the ground. They are used both for causal snacks as well as in formal dining.

The seeds are also important foods. The kernels are made into a spicy sauce, and they also provide the so-called neou oil, which is renowned in Sierra Leone as pomade. The kernels are said comprise 62 percent oil—a

[7] This fruit is also called gawusa (Hausa), buwell (Jola), and tamba (Mandinka), as well as, it is said by some, rotten plum.

very large amount.[8] Nutritionally speaking, the oil is of fairly good nutritional quality, with considerable amounts of unsaturated fatty acids.[9]

This species is esteemed for many additional products. The rind from fresh fruits is used to impart a pleasant scent to ointments. The living tree provides villagers with dye, glue, fodder, firewood, soap, structural materials, and even termite repellents (in the Gambia). And the leaves are used medicinally for such things as toothache and mouthwash.

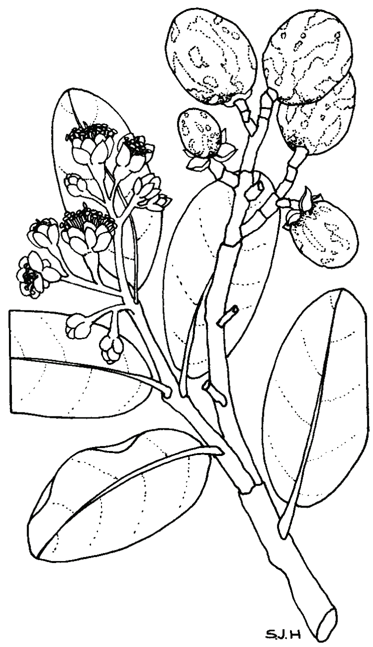
OTHERS

Related species with edible fruits can be found throughout Africa. Whether any are worthy of development as food crops cannot presently be judged, at least from a distance. Examples include:

- *Parinari benna* Scott-Elliot (*Bafodeya benna* (Scott-Elliot) Prance ex F. White). Tree similar to the rough-skinned plum. Guinea.
- *Parinari campestre* Aubl.. Fruits of a pleasant flavor. Guinea.
- *Parinari congensis* Didr. A rainforest tree. Equatorial Africa.
- *Parinari emirnensis* Baker. Vandevenona. A tree of central Madagascar.
- *Parinari goetzeniana* Engl. An evergreen rainforest tree growing to a height of 25-50 m. East Africa.

[8] Dalziel, J.M. 1937. *The Useful Plants of West Tropical Africa*. The Crown Agents for the Colonies, London.

[9] Hilditch, T.P. and P.N. Williams. 1964. *The Chemical Constitution of Natural Fats.* Chapman and Hall, London. According to an early analysis, it contains 8 percent palmitic, 4 percent stearic, 44 percent oleic, 16 percent linoleic, 1 percent linolenic, and 4 percent licanic acid.



Parinari curatellifolia

6

GUMVINES

The latex-filled stems of the genus *Landolphia*[1] once produced all the rubber for Senegal and Sudan and some of the rubber for other African nations. Part of the harvest was even exported to Europe, where it was esteemed. Commercial interest in these plants collapsed only when, in the early 1900s, Brazil's rubber tree (*Hevea brasiliensis*) began dominating world production.

The problem was not the quality of the rubber. The African plants were superseded because, being vines or climbing shrubs, they are hard to handle in horticulture. Further, they had never been brought into organized cultivation, and harvesting latex from scattered wild plants cannot compete with organized plantation production, even in the rubber tree itself.

During World War II, when the Allied Powers were cut off from Southeast Asia's huge rubber production, interest in Africa's so-called gumvines picked up once more. However, the wartime crisis passed before much product could be supplied. The subsequent perfection of synthetic elastomers then seemed to forever seal the fate of Africa's own native rubber supply. People gave up on these crops, which have since remained mere curiosities of minor local historical interest.

Now, however, international interest should pick up once more. Some *Landolphia* species bear masses of fruits that are very pleasant to the taste buds. A few of these "gumvine fruits" or "rubber fruits" are yellow and furry and look somewhat like apricots; most, however, are more like an orange with smooth tough skins that are reddish, yellow, or orange in color.

These fruits are frequently seen for sale in markets across West Africa. In Mali, Burkina Faso, and neighboring nations it is also common to see young boys selling clusters of them along the roadways. The juice from these fruits is regarded as extremely healthful, probably with good reason. In addition to a normal nutritional content for fruits, some have vitamin C levels approaching oranges. At least one species, *Landolphia hirsuta*, provides

[1] *Landolphia* taxonomy is tangled, with much overlap among scientific and common names. Further, some botanists transfer all *Landolphia* species to the genus *Saba*, some refer a number of them, including *L. capensis* and *L. kirkii*, to *Acylobothrys*. However, most of the literature is still to be found under *Landolphia*.

Landolphia lanceolata photographed beside a highway in western Congo (D.R. Congo). Boys peddling clusters of gumvine fruits are a common sight across West and Central Africa. The fruits are sweet, juicy, and can provide good provitamin A. Of all Central Africa's fruits these are the ones most commonly offered in markets and along the roadsides. This popular food remains a wild resource, but it holds much promise to help rural peoples produce highly salable products in some of the world's most horticulturally challenged regions. (Paul Latham)

good levels of provitamin A, and all gumvines share the same tell-tale yellowish carotenoid color. People often use them to season rice, maize, and other cereals; to prepare refreshing, lemonade-like drinks; to make a type of beer; and to flavor foods such as fish. In The Gambia, and perhaps elsewhere, gumvine is used this way as a condiment in place of limejuice.

At least 17 *Landolphia* species—perhaps a hundred or more—occur in tropical savannas and forests, notably in West and Central Africa. They are common forest lianas and sprawly shrubs noted for their jasmine-scented flowers as much as for their plentiful fruits or latex-filled stems.

Currently, little importance is attached to the plants as potential income sources. But if they can be tamed and turned to use, tropical Africa will have a collection of new, interesting, and appealing crops that could contribute much to nutrition and perhaps much to economic well-being as well. If particularly good specimens can be located and produced in quantity, there is even the possibility of exports, because these fruits tend to have shelf lives long enough for ocean travel.

All in all, rubber fruits offer good projects for plant lovers and progressive farmers throughout the African tropics. In addition, scholars in France, Belgium, Germany, and Britain could help the cause by scouring the

colonial archives and botanical records for horticultural information recorded during both World War II and the earlier rubber-producing era. This could be most useful because the musty old documents are difficult for outsiders to access today, and the results of all the earlier work are essentially lost to worldview.

Even armed with such information, organizing rubber-fruit production will not be easy. Viney plants are horticultural horrors. They require supports, and their climbing or spreading growth habit makes them hard to manage. Nonetheless, the world's biggest fruit crop (grapes) comes from a vine, as do some fast-developing newcomers (kiwifruit and passionfruit, for example). Adapting management techniques from those (or from vanilla, for that matter) may provide the keys for domesticating rubber fruits.

In this regard, then, pruning, training, and general horticultural improvement should be explored. In addition to using trellises and pergolas, the concept of training these vines on trees should be evaluated. If successful, rubber fruits could raise the economic value of standing forests—thereby dampening the ardor to burn those forests down for land or cut them up for lumber. Perhaps rubber fruits could also help shifting-cultivators by providing food and income while they wait out the weary years for the land to restore itself. In fact, fruits in many other parts of this report might be used for such "fallow enhancement"—both protecting the soil and producing at least a small something to eat or sell on the side.

Other agroforestry interventions should be tested as well. Incorporating gumvines into boundary tree rows, windbreaks, shelterbelts, and *ex-situ* conservation forests are possibilities.[2] Plants such as these that cling onto something could be a way to increase the utility of many long-term environmental tree-plantings. On the other hand, caution is needed because these vines are vigorous and get to be very heavy if left unmanaged. Indeed, these vines would seem to be ideal wherever dense, interwoven "nets of living vegetation" could prove useful. In village settings they might also be trained along fences, up walls, or perhaps over roofs.

Paralleling such endeavors should also be farmer-participation programs. This is needed because at present farmers offer more insights than science. Their experience together with researchers' training make a uniquely powerful intellectual cocktail for progress. Wild stands are especially appropriate places for local participation. And any efforts to advance gumvine fruits should include *in-situ* conservation to preserve those stands.

Despite all the promise and possibilities, organizing commercial production presents grave horticultural challenges. In the wild, gumvines do not fruit every year, nor do the plants form their fruits all at the same time.

[2] The process of weaving vines among the trees is already practiced in Africa. An orchardist in Djenné, Mali, for example, plants a thorny climber (*Acacia pennata*) among neem trees to create a barrier to both wind and animals. Malians also plant thorny *Capparis* vines among their trees to equally good effect. Information from D. Osborn.

Also, it is reported that some species take as long as 12 months to mature each crop of fruits.

However, such difficulties probably reflect merely our primitive state of knowledge. Although little effort has been made to propagate the vines, this seems not to be problematic. Freshly collected seed normally germinates well.[3] Selected plants can also be propagated via cuttings. Production can be exceptional: Vines yielding 200 fruits have been recorded, and even better specimens undoubtedly await discovery. Indeed, throughout Africa gumvines are renowned for the often-enormous burden of fruits hanging around them on all sides.

Genetic selection and domestication are important for turning gumvines into fruit crops. Finding quality types and developing horticultural methods that speed up production are two keys to success.

Following are gumvines possessing potential as future fruit crops.

RUBBER VINE

The so-called rubber vine (*Landolphia florida* Benth.)[4] is perhaps the most common gumvine. Its fruits are eaten in many parts of Africa. They are round or slightly pear-shaped and are about the size of grapefruits. Their thick and leathery rind is yellow to orange in color, dusted with a whitish "bloom" at maturity. The inside is full of soft, reddish pulp within which are embedded a few seeds.

The succulent, smooth, and either sour or agreeably subacid pulp pulls away easily from the rind. Normally, the seeds are picked out and the remainder blended with water and sugar. The resulting beverage is consumed either fresh or fermented, and is said to be most pleasant.

The species occurs in lowland rainforests and flourishes on a variety of sites and soils. It is a liana, climbing up the sides of trees as high as 20 m. Its stems are stiff enough to make useful walking sticks, and sometimes they are intertwined between fenceposts to construct corrals capable of holding cattle overnight. Fruits remain on the tree when ripe and can be "stored" there on the vine till needed.

SABA

The saba (*Landolphia senegalensis* (A. DC.) Kotschy & Peyr.)[5] is an "upwardly mobile" plant of tropical West Africa and the western Sudan.

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[3] A success rate of over 90 percent has been reported, but apparently the seeds must be clean and fresh; dirty seeds lose viability in just weeks.
[4] Synonyms are *Landolphia comorensis*, *Landolphia comorensis* variety *florida*, *Saba florida*, *Saba comorensis*, and *Vahea senegalensis*. Common names include rubber vine, aboli, saba du Sénégal (French), and anoma (Ghana).
[5] A synonym is *Saba senegalensis* (A. DC.) Pichon.

Typically, this woody vine clambers up the fringes of the forest. It is a high climber when trees are available to support its ambition to get to the top, but in more open and dry lands it remains a lowly shrub.

Saba fruits are orange on the outside and pale yellow inside. They have a thick, rough rind. Most are about the size of a medium to small orange. In taste, they are acidic, almost like a strange form of citrus, which they nearly match in vitamin C content. In parts of Africa, they are important to the rural economy, and many are trucked or carried in baskets to sell in the cities.

These colorful treats are, for example, widely consumed in Senegal and the Gambia. They are full of big seeds that are coated with an aromatic sweet and sour flesh. Most are eaten as casual snacks, but some are employed even as a staple—especially during the rainy season. They are also blended with water and sugar and made into fruity beverages. One of our contributors calls them, “fantastic for exotic juice.”

The vines themselves have uses too. They make beautiful ornamentals. And they do more: homeowners even use the almost unbreakable vines to tie down their roofs. In addition, the latex-filled sap is used to mend bicycle tires, football bladders, and so forth. And the long lianas are made into “ropes,” with which to scale trees (for tapping palm-wine, for instance, or collecting nuts).

WILD APRICOT

One of the plants English speakers in tropical and southern Africa refer to as “wild apricot” is actually a native rubber fruit (*Landolphia capensis* Oliver). This sprawling shrub, for example, rambles over rocky ground in South Africa (notably Gauteng). In season, groups are commonly organized to go out and gather the large, yellowish-red fruits on the hillsides and plains. Their tasty flesh can be sucked directly, but the parts immediately around the seeds are very sour. The fruits are also fried or made into preserves, jellies, vinegar, or “brandy.”

Like its relatives, this plant’s stems ooze latex when cut.

WILD PEACH

This strong climber (*Landolphia kirkii*) abounds on rocky, wooded hillsides in eastern and southern Africa (Somalia to South Africa), especially in the high-rainfall parts. In the past it was East Africa’s most important rubber plant. The extracted latex is of good quality: high in rubber, low in resin. It was once known worldwide under the name “Zanzibar rubber” and was a major export of German East Africa (today’s Tanzania).

As a result of past commercial significance, the species was sometimes cultivated. Colonial records contain information on planting, managing, and tapping for latex. Today, the plant is rarely if ever cultivated—and perhaps there is no need as it is plentiful in the forests, where it readily reseeds itself.

EATING ETA

After cracking open an eta fruit one sees the seeds and pulp clinging together in a tight ball, quite loose from the outer shell. People eat this in different ways. Some use a finger, knife, or other utensil to separate the seeds so they can be eaten individually. Others tip back their heads and shake the whole mass into their mouths. Most of us do it that way, swallowing the seeds after swishing the fruit around for just a couple of seconds. Speed is needed because the aromatic sweetness soon turns sour and intensifies until almost unbearable.

We found one eta fruit, however, that never turned sour. Eating it was a whole new experience. Also, the flesh was separated from the seeds, an exceptionally desirable trait. Seeds from this particular fruit were planted at our experimental fruit farm in Congo, but we don't yet know if they too will bear sweet and cling-free fruits.

The point is, a lot of variation is to be found and it might provide many unexpected ways for advancing this crop. (Roy Danforth and Paul Noren)

Fruits of this gumvine are round, speckled, and sized like mandarin oranges. They are popular with those in the know, but their tartness can put off the uninitiated.

GUINEA GUMVINE

Despite its common name, guinea gumvine (*Landolphia heudelotii* A. DC.) occurs throughout most of tropical Africa from Senegal to Tanzania

and as far south as the Congo area or even Angola. It is a characteristic feature of the vegetation on the interior plateaus throughout this vast area. Mainly a savanna and understory shrub, it is often found in open forests and on laterite and sandy soils near rivers.

This climbing vine or spreading shrub once was the main rubber supplier to Senegal, Guinea, and the French Sudan (modern Mali). Some of its rubber reached Europe. A century ago, farmers were encouraged to cultivate the plant in gardens and farms, particularly after the wild vines were so decimated that the rubber supply began dropping. Propagation was both by seeds and cuttings.

The sap is even today used locally to fix bicycle tubes. However, the fruits are now much more important than the rubber. Small (3 cm in diameter), round, and yellow to orange in color, they sell well in markets. The pulp surrounding the seeds is filled with a juice that is regarded as very healthful and is sometimes prescribed as an aid to digestion. Rich in organic acids, this pulp is used as a snack, as a breakfast food, and as a source of refreshing drinks. Beer is also made, and the juice is commonly used to season rice with its sprightly sourness. In some countries—The Gambia, for instance—it is especially important during the "hungry time" each year.

The plant grows under trees and is promising for agroforestry. Farmers are likely to grow it eagerly, whether they really want fruits or not. To them, it is a self-replenishing annual fodder reserve. Goats like the desiccated leaves, and the plants thereby help a farmer's "cash on the hoof" survive the dry season.

ETA

The eta (*Landolphia owariensis* Beauv.) is found in tropical Central and West Africa.[6] It grows as a vine in forest; as a shrub in savanna. At the turn of last century it was a major source of rubber produced in Sierra Leone, Ghana, Nigeria, and perhaps other nations as well. Today people make rubber bands out of the cured latex, but this is increasingly rare.

The fruits, however, are widely eaten. They are the size of oranges and have a reddish-brown, woody shell and an agreeable pulp. This pulp is eaten directly. It is also used to season foods and to make tangy fruit drinks and even wine. Typically, the flavor is both sweet and sour at the same time.

Eta is an unusual fruit, but people really like it. Normally, the pulp is merely dumped in water and left to soak a few minutes. Being highly acidic, it makes a lot of beverage. Sugar is added to taste, and the final product conveys a delightful aroma.

The tough and leathery skin is usually opened with a whack of the fist or heel of the hand. (It can be cut open, but latex in the thick outer shell soon gums up the knife.)

[6] It is also known as abo and Congo rubber.

Seeds and cuttings are the usual means of propagation.[7] For the first couple of years the plants are slow growing and remain short and stubby bushes, but they then begin elongating and take on the appearance of vines. At that time they are removed from the nursery and planted in the field. If given a chance, this gumvine grows straight up the trunks of trees, making its way to the top of the forest canopy.

The twigs, like other gumvines, are also used as chewsticks.

OTHER GUMVINES

Below are mentioned several other species worthy of evaluation, which should be based on a fruits' qualities rather than taxonomy.

Landolphia petersiana Dyer This little-known eastern African gumvine bears apricot-colored, pear-shaped fruit that some experts consider to have more potential than wild peach (p. 275). It is sweeter, tastier, and more attractive than its better-known cousin, and therefore, they say, more saleable. Its flavor has been likened to guava, but so far no one has done much to explore the plant's crop potential. The fruit is found in essentially the same range as wild peach—from Natal in South Africa through Mozambique and Tanzania, north as far as Somalia. It, too, is associated with tropical forest and bush. The plant is a sprawling shrub or woody liana, with tendrils. Its sweetly scented white flowers are cluster in panicles at the end of the branches. The fruit is more or less round, with numerous seeds embedded in the soft pulp. It is eaten when both ripe and nearly ripe. The ripe fruit is eaten skin and all, but the semi-ripe fruit must be first peeled.

Landolphia ugandensis Stapf This large vine, the source of nandi rubber, is found at elevation (1,200-1,500 m) in Uganda. The rubber is obtained by shaving off slices of the bark and smearing salt water onto the cut surfaces, which then ooze latex.

Landolphia buchananii Stapf Generally associated with forested environments in eastern Africa (Mozambique, Tanzania, and eastern Zimbabwe are reported), this vine bears yellow fruits as big as oranges.

Landolphia parvifolia K.Schum. A plant found mainly on the shores of lakes in Malawi as well as in nearby Zambia, this gumvine bears edible greenish-purple fruits the size of plums or peaches.

Landolphia calabarica (Stapf) E.A.Bruce This gumvine of Ghana has edible fruits up to 10 cm wide and 12.5 cm long. Rubber was once derived from the stems and roots.

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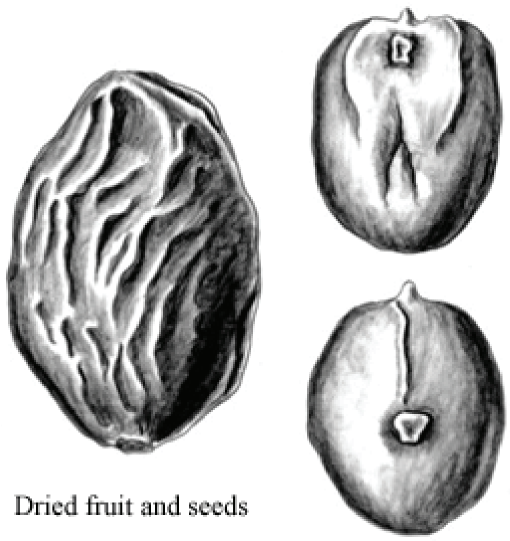
[7] Information from R. Danforth.

Landolphia dulcis* var. *barteri (Stapf) Pichon This pointy fruit, which looks not unlike a cocoa pod, is found in fallowed forest in West Africa.[8] The roots are renowned for their supposed effectiveness as an aphrodisiac. Recorded in Senegal, common in ravine and gallery forests of moist climate ecozones. Also recorded as a sweetener in Sierra Leone.

Landolphia hirsuta Beauvois is harvested from wild forests in Côte d'Ivoire. A rare nutritional analysis showed that merely three fruits (about 100 g edible portion) provide for almost 2/3 the daily vitamin A requirements of a 7-9 year old child.[9]

Landolphia capensis

[8] Information from S.C. Achinewhu. The plant is known in Nigeria as mbelekwulekwu.
[9] Herzog F., Z. Farah and R. Amadò. 1994. Composition and consumption of gathered wild fruits in the V-Baoulé, Côte d'Ivoire. *Ecology of Food and Nutrition* 32:181-169.



Dried fruit and seeds

7

ICACINA

Icacina (*Icacina oliviformis*)[1] is a small, drought-resistant shrub forming dense stands in the West African and Central African savannas. It is remarkable for yielding three fundamentally different types of food: a snack, a staple, and a famine food. In a sense, icacina (pronounced ik-a-SEE-na) is a living grocery store during normal times and an emergency relief-food supplier during hungry times.

Although the plant is essentially unknown to agronomists, horticulturists, or even the technical literature, several million people rely at various times upon its three different products: fruits, seeds, and tuberous roots. The fruits, for instance, are widely enjoyed during the annual harvesting season. Bright red and plum-like, they are sweet and usually consumed fresh. Plants can grow so densely and yield so exuberantly that a family can sometimes collect several hundred kilos of fruits a day even from untended wild stands.

The seeds from the center of the fruits are also edible. They, too, are often plentiful. Dried, they turn rock hard, but then can be stored with negligible loss. In a test in a mouse-infested storeroom, for example, seeds remained untouched during several weeks. This is an important attribute because icacina grows where people lose a lot of food to rodents and insects. However, the seeds contain bitter substances and cannot be eaten directly. They are soaked several days, boiled in new water, dried, dehusked, and ground. The result—a floury solid with a rich, nutty flavor—takes a lot of work to make but it is greatly appreciated, especially where diets are bland staples such as cassava.

The third edible product is a fleshy, tuberous root. Known widely as “false yam,” it resembles turnip or beet but can grow to giant size, sometimes weighing more than 60 kg. The usable portion is about 80 percent starch and a crucial resource during famines. People leave them underground until absolutely needed. The tubers are then sliced and soaked in clean water for several days to soften the flesh and leach out bitter compounds. They are then dried in the sun, pulverized, and sieved. What results is a white, grayish, or creamy-yellow flour. Drying the damp flour in a pot over a fire produces clear, hard “rocks” of what is probably almost pure starch.

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[1] *Icacina senegalensis* is also still widely used as the botanic name.

The giant tuber is such a great source of emergency moisture and food energy to the plant that it can survive at least four years without rain. Thus, as long as icacina is around food is always available for people too. This rugged shrub is the traditional emergency reserve for use in the absolute worst of times when even pearl millet succumbs.

In better times, however, icacina can save lives too. Its fruits ripen as the dry season comes to an end, the very moment when the stores of other foods often run out. In the northern parts of the Central African Republic, for instance, hordes of people each year mount expeditions to collect the fruits and keep themselves fed during the few most-threatening weeks when little else is on hand in the villages.[2]

Despite its vital value to the hungry, icacina has never been fully domesticated or even investigated horticulturally. Nonetheless, it could be produced in far greater amounts. Indeed, it has a future as both a subsistence and commercial crop. The species is easy to grow and is already sometimes cultivated in gardens (at least in Senegal). It is also easy to harvest because the bush seldom exceeds 80 cm in height and bears its fruits near the outside, where they can be reached without difficulty. Even mechanical harvesting seems feasible.

In part, this crop has suffered because of its common name. The words “false yam” confer a sense of illegitimacy. Among the better educated, many consider it a rogue plant…or even a dastardly weed. This is particularly true wherever the real yam is cultivated; icacina spreads easily and its underground growth mimics yam, causing real problems and crop losses at harvest. But no one should write off icacina hastily. Indeed, in certain areas it might prove to be a better source of commercial starch than the yam itself. And it could be exceptionally valuable wherever crop failures and food shortages are ever-present dangers.

In part, this resource has also suffered because it is a shrub. Although an especially hardy life form, shrubs are generally neglected in development activities. Too big for agriculture; too small for forestry, they fall between the disciplinary cracks. Icacina is a prime example of how the world misses out on valuable woody resources merely because they have branches where they should have trunks.

Efforts should be made to explore this species’ possibly substantial agricultural potential. Even in the wild, it grows in a natural monoculture; pure stands with over 400 plants per hectare have been recorded. In the exploration of this possibility lie fascinating challenges to researchers, entrepreneurs, and other pioneer movers and shakers. Icacina perhaps doesn’t deserve massive international efforts, but a few motivated “crop champions” could likely transform this plant and bring to more Africans a new resource and a new level of food security.

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[2] Information from Michael Fay, the individual who has done more than perhaps anyone to draw international attention to this plant and its promise.

The bright red fruit of icacina contains a sweet, sought-after pulp. The seed, after processing, yields a tasty and nutritious flour, as does the tuber. Though always popular, icacina can take on crucial importance during times of famine. This extremely drought-tolerant shrub is easy to grow and is already sometimes cultivated. (Marco Schmidt)

PROSPECTS

Success with icacina is uncertain, but could be outstanding. Although untouched by agronomic science, the plant is already widespread and depended on by millions. Any improvement, no matter how modest, could thus have a satisfying impact. To consider icacina as just a weed or fallback crop for the worst of times is quite wrong. People truly enjoy the fruits as well as the seeds, which represent a permanent, reliable, and very tasty food.

Within Africa

Humid Areas Prospects here are high. The plant grows both in the forest (at least along edges) and savanna areas.

Dry Areas Prospects here are even higher. This could be an outstanding life-support species for the Sahel and for the equally drought-fraught areas of Ethiopia, Somalia, and southern Africa.

Upland Areas Potential here is unknown, but perhaps worth finding out.

Beyond Africa

Prospects here are probably low. Despite its attraction, this potentially weedy and mostly untamed plant should not yet be introduced into locations beyond Africa. Even exploratory trials are not justified at present.

USES

As has been noted, the fruits are eaten fresh. They are a particular favorite of children.

The seeds, in addition to roasting, are sometimes dried and pounded into flour, which can be stored for use especially during times of food scarcity.

The tubers, too, are used in the form of flour. Despite the need for processing first, and sometimes a slightly bitter flavor, icacina flour is commonly used to make pastes or porridges. Composed mainly of starch, the flour nonetheless can contain up to about 10 percent protein, a remarkable amount for a root crop—five times that in cassava flour and twice that in potato, for example. It can be stored until needed.

NUTRITION

Owing to a lack of data, there is not much to report here.

Fruits Regarding the fruit's nutritional quality, no basic information is yet available. They are eaten fresh, but are often sun dried as well.

Seeds In one analysis, flour extracted from the seeds was about 13 percent moisture, 72 percent carbohydrate, and 8 percent protein, with little fat (about 0.1 percent) or ash (about 0.5 percent).[3] As noted, before they can be eaten they must be soaked to remove somewhat bitter compounds (see Next Steps). Seeds are normally boiled and eaten directly, but can also be redried for further storage or pounded into powder like cassava or sorghum.

Roots The tubers contain about 10-15 percent starch. The starch granules are irregular in shape and size, some spherical and some elliptical, with diameters varying from 12 to 50 microns. Roots, too, can contain toxins unless properly processed.

AGRONOMY

Information on best cultivation practices has yet to be developed. No particular pests or diseases are reported, but this is perhaps only because the plant is so little studied.

The tubers are harvested only when required. Owing to their size and the fact that they can penetrate far below the surface, they are difficult to dig out.[4] In Senegal yields have been reported to average 2-3 tons per hectare; elsewhere in West Africa yields are reported to reach 20 tons per hectare. For a wild and untended plant, these are remarkable amounts.

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[3] Kay, D.E. 1973. *TPI Crop and Product Digest No. 2, Root Crops*. Overseas Development Administration, London:

[4] For this reason the plant has been nicknamed "break hoe" (abub ntope) by the Ashanti of northern Ghana.

LIMITATIONS

Most fruits have only small amounts of pulp.

Both tubers and seeds contain bitter compounds that must be washed out.

Roots are difficult to lift from the soil and their preparation is arduous.

The plant can be troublesome in savanna lands and along roadsides. Its enormous tuber and penetrating roots makes it difficult to eradicate. It is renowned for destroying not only shovels and plows, but people's patience.[5]

NEXT STEPS

Although this life-saving plant deserves much greater recognition, exploratory investigations are mainly what are needed for the moment. Actions likely to provide an across-the-board picture of icacina's practical potentials include those given below.[6]

Extension Support Helping current icacina users is one thing that doesn't need to be approached on an exploratory basis. Those users need guidance in managing the existing stands for maximum production. However, extension services could also develop ways to increase the size and density and productivity of the wild stands. This would help provide the ultimate in food security, not only filling bellies down the decades but also helping save the populace when disastrous droughts arise.

Genetic Selection Knowing any crop's capabilities is fundamental to its future development. But at present no one knows those capabilities for icacina. Thus, there is a need to build a background of reliable knowledge by collecting both knowledge and germplasm, and comparing different features such as fruit size and flavor, seed size and palatability, resistance to pests and diseases, rate of growth, and other important horticultural attributes. From that base of knowledge should arise highly productive and resilient shrubs with shapes (open bottoms, for example) that are best for purposes of weed control, ease of harvest, and general management.

Documenting Traditional Knowledge Because this plant is so new to science but so old to Africans, it is vital to document the methods and practices traditionally employed for handling and using it. That will avoid having to reinvent ancient wheels of knowledge. Even though scientists may not know much about this plant, rural peoples know a lot.

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[5] To remove icacina in Casamance (Senegal), people cut the upper part of the plant and burn the remaining portion at the beginning of the rainy season. But sometimes a portion survives and produces a new shoot anyway. Information from Venceslas Goudiaby.

[6] In all research activities it should be borne in mind that this plant might become troublesome. The enormous tuber—30-45 cm long and 30 cm or more in diameter with long penetrating roots—requires much labor to eradicate.

Publicity and Promotion This crop has unwarrantedly been dismissed as just a "famine food." It does serve that purpose, but much of the early literature is filled with misleading inferences that are still repeated to the crop's detriment. Needed now are actions to break through the "inferior food" image and give the plant the prestige it deserves. Means to this end might include simple activities such as putting out an icacina cookbook, holding contests for best recipes, or serving icacina at prestigious functions.

Plant Physiology and Botanical Studies For proper progress we need to better understand the plant's physiology and phenology. Such things as pollination and seed set, tuber growth, seed viability, pruning, and possible daylength requirements deserve rapid "agricological assessment." Checks of icacina's environmental limits—climate, soils, altitude, moisture requirements, and the rest—should also be included as part of this general endeavor to build a clearer picture of the plant and its normal needs.

Toxicological Studies Although widely eaten, there exist some safety concerns about the seeds and tubers, at least of some species.[7] How hazardous, for instance, are the bitter chemicals that are **not** washed out of the seeds and/or the tubers? Are any residues left in the flour? How good does the preparation need to be for safety? Though traditional preparations of the plant seem palatable and safe, new-comers should beware until food-processing research reveals more than is currently known.

Horticultural Development Although the plant is sometimes cultivated, it is only on a very small, household scale. Agronomists should begin experimental trials to determine the main features limiting growth and productivity. These might include trials to see what maximum production levels can be when the plants are fertilized and well cared for in good, deep, loose soils. How does management differ for fruit/seed vs. tuber production? This could include trials on horticultural manipulations such as pruning flowers to remove them as an energy sink and thereby improve production of underground parts. And there should be a check of seed germination, which is a possible difficulty through the seeds having a short longevity.

Moreover, better methods of handling the tubers are also needed. Investigations should be undertaken to assess the promise and pitfalls of

[7] Extracts from some species have been shown to induce sleepiness and reduce pain in rodent studies (Asuzu, I.U. and I.I. Abubaker. 1996. The emetic, antihepatotoxic, and antinephrotoxic effects of an extract from *Icacina trichantha*. *Journal of Herbs, Spices & Medicinal Plants* 3(4):9-20) but also to contain hydrocyanic acid, phytic acid and oxalic acid—the same bitter principals as cassava, a global staple (Antai, S.P. and G. Nkwelang. 1999. Reduction of some toxicants in *Icacina mannii* by fermentation with *Saccharomyces cerevisiae*. *Plant Foods for Human Nutrition* 53(2):103-111).

mechanized harvesting. Although the giant size of the old roots makes them hard to harvest, those pulled up on an annual basis would be smaller and much easier to lift from the soil. Cassava is also a shrub, so this possibility is not as far-fetched as it may seem.

Nutritional Studies Nutritionists in West and Central Africa should check into local food uses of icacina and evaluate any impacts on nutrition and/or malnutrition. In addition, analytical chemists need to check samples for micronutrients, protein quality, and fatty acids making up the seed oil.

Famine Food Trials Icacina helps those most at risk in drought times. It deserves organized testing in dry zones in various parts of Africa to see how it survives within and beyond its current range. A perennial that produces large quantities of three different foods could be a valuable food-security crop for the most difficult regions and most threatening times. The Horn of Africa—especially Ethiopia's chronically drought-stricken Ogaden province—comes to mind as a good place to start confined trials.

Food Technology Better methods of extracting starch from the tuber should be developed. Current processes can be extremely wasteful, with sometimes only 10 percent of the raw tuber's starch being recovered. The root is not unlike cassava; various methods developed for handling cassava and its products could provide invaluable leads. Success might instantly turn this wild resource into a cash crop for regions with few salable materials.

Forestry Perhaps this woody plant could also make a useful firewood crop, with the fruits and roots coming as a bonus. Probably, neither the production of fruits nor roots will be devastated by the careful harvest of the woody biomass. It's well known that it's very difficult to eradicate the icacina tree because the plant is constantly refreshed from its deep tuber.

SPECIES INFORMATION

Botanical Name *Icacina oliviformis* (Poiret) Raynal

Family Icacinaceae

Synonyms *Icacina senegalensis* A. Juss.

Common Names[8]

English: icacina, false yam

[8] A full list of local names is in Fay, J.M. 1987. *Icacina oliviformis* (Icacinaceae): a close look at an underexploited crop. I. Overview and ethnobotany. *Econ. Bot.* 41(4):512-522

French: bankanas
Senegal: furabã, kurabã (Diolas), mãnkanaso (Mandingue), bãnkanas, ndangam (Wolof)
Gambia: manankaso
Ghana: takwara, abub ntope (northern Ashanti)
Hausa: tankwara
Sudan: Pané
West Africa: basouna

Description

Icacina is a shrubby perennial showing considerable variation in form. At or before the beginning of the rainy season it throws out erect leafy shoots from a large underground fleshy tuber. Its aerial stems can reach almost 1 m in height. The five-petaled flowers are inconspicuous, usually white or cream, and pedunculate on an ascending panicle.

The fruit is a bright-red ovoid berry, approximately 2.5-3 cm in length and 2-2.5 cm in width. It is covered with very short hairs and contains a thin layer of white pulp, approximately 0.2 cm thick, surrounding a single spherical or ovoid seed.

The tubers show considerable variation in size, ranging up to 100 cm in length, with a diameter of about 30 cm. They are typically 50 cm wide and weigh 10 kg or more. They have a thin, grayish skin. The flesh is white and is usually speckled with yellow spots (corresponding to bundles of free xylem). It contains bitter (and perhaps toxic) principles.

Distribution

Indigenous to West and Central Africa, icacina is found in the savanna areas of Senegal, Gambia, Guinea, northern Ghana, Benin, Nigeria, Central African Republic, Congo (both), Chad, and parts of Sudan. Even in those areas where it is abundant collections have been scanty, and it likely occurs in many more areas than are now described. Nonetheless, there appear to be three locales of especial abundance: Senegal and Guinea-Bissau, Ghana, and Central African Republic.[9]

Related Species

Although the taxonomy of these plants is not too firm, there seem to be six *Icacina* species. All are African. Three more with edible parts are:

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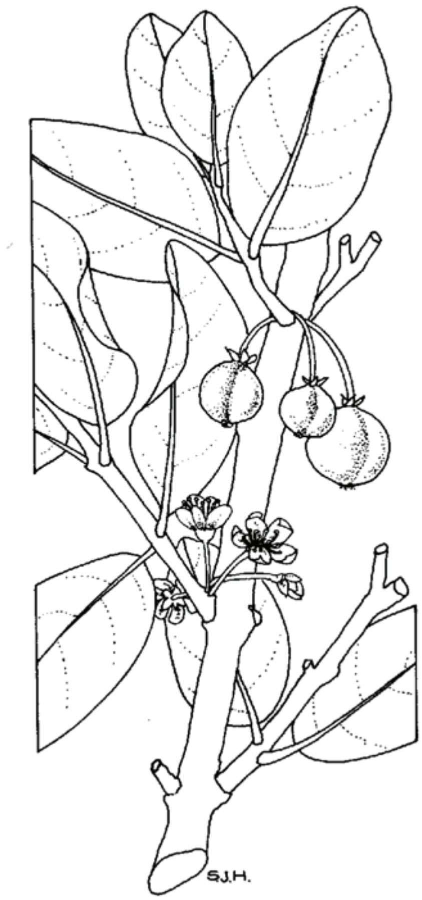
[9] One cannot discount the possible role of people in this unusual distribution pattern. Information from M. Fay.

Icacina mannii Often called *mumu*, this species is found from Congo to Senegal. Its fruits, seeds and tubers are all edible, at least after proper preparation. The pink pulp of the fruit is eaten at least in Congo, Senegal, and Guinea. The seeds are steeped for a week in water, which is changed each morning to remove bitter elements. They are then left in the sun two days to dry. Finally, they are reduced to flour by pounding. The resulting meal can be mixed with that of millet or beans to make a thick paste (known as enap in Senegal). The tuber is cut up and leached in running water to remove toxic elements and facilitate maceration. The pieces are afterwards dried, pounded, and strained to remove fibers. The starchy flour is then either eaten without further processing or, more often, is blended with the flour from the seeds. It is also softened into an edible paste by the addition of boiling water.

Icacina claesensi Called kukbukumbu in Congo.

Icacina guessfeldtii. The fruit is reportedly eaten in Congo.



Garcinia livingstonei

8

IMBE

Asia's mangosteen is commonly called the world's most delicious fruit. However, the plant producing it (*Garcinia mangostana*) happens to be only one of 400 *Garcinia* species found in Asia and Africa. Some of the lesser-known examples also have delicious soft fruits, while others produce chewy nuts described as "falling somewhere between fruits and chewing gum."

Africa's best-known mangosteen relative is the imbe,[1] a tree whose soft and colorful fruits brighten up markets from Senegal to South Africa. Its botanical name, *Garcinia livingstonei* T. Anderson, derives from Dr. David Livingstone. In the East African area through which the legendary explorer wandered during the 1860s, imbe is known as "the King of Fruits." The pulp of these small, orange-colored delights is juicy, pleasant, and sweet-to-acid on the tastebuds. Even those specimens that are unusually sour are considered agreeable and refreshing on a hot afternoon.

Imbes come from a shrub or small tree with a dense spreading or conical crown topping a short, often twisted trunk or cluster of trunks. The effect is a tree that seems to grow strangely off-kilter. Its unsymmetrical shape and stiff, dark leaves create a striking appearance. This unusual and eye-catching form, together with the year-around foliage and heavily scented flowers, make it a landscaper's dream. As a result, this tree is today planted more for beauty than for food. It has, for example, long decorated Mozambique's capital. Many Maputo streets are lined with imbe trees, providing shade to all and fruits to some (mostly kids waiting for the bus to school). Imbes also beautify the landscape around the famous Victoria Falls.[2]

But in the opinion of many who know this species, the imbe is a candidate for domestication and for much more intensive use in Africa's lowland tropics and hotter subtropics. A host of specific reasons support this opinion: Many African peoples already relish the fruits. Even in its present

[1] Commonly also called wild plum, wild mangosteen, pama, gupenja, and mwausungulu.

[2] "I've just come back from the Zambezi Valley below Victoria Falls Gorge," wrote Ray Perry, one of our contributors. "The *Garcinia* were in full blossom (September). What a wonderful smell. The trees were alive with insects and birds. Bees obviously love the flowers. There was also a small moth around the trees. There are many 10 m tall specimens, but the species seems to only grow along the river courses."

This eye-catching imbe tree with a dense crown makes a striking sight. This, together with the year-around foliage and heavily scented flowers, make it a landscaper's dream. As a result, this tree is today planted mostly for its good looks. However, the plant happens to be related to Asia's mangosteen, generally considered the "world's most delicious fruit." Imbe's colorful fruits brighten up markets from Senegal to South Africa but they have yet to be produced in anything like substantial commerce. (Steve Flowers)

unimproved state, the species produces abundantly. The trees integrate well into the village scene and make excellent partners in mixed-crop farming. Farmers are almost promised a profit because the general populace places a high value on these fruits—indeed, demand is so great it often cannot be filled. The fruits themselves are already attractive and of a good size for mass marketing. The trees are adaptable and thrive in adverse sites, including dry, damp, sandy, or rocky locations. Although not overly particular as to soil, the trees respond vigorously to good culture. Finally, they make excellent village-, farm- or dooryard companions, being tall enough to throw soothing shade over people, paths, and patios.

Unfortunately, however, little is currently known about how to grow this plant as a food crop. Despite common occurrence and widespread popularity, its production under cultivated conditions remains basically undocumented. Given this paucity of experience, imbe's commercial future must therefore be considered uncertain. Nonetheless, further horticultural exploration should be undertaken with vigor, as this seems likely to unleash a new, nutritional, and notable indigenous resource.

Even without their fruits, these highly ornamental trees are good to have around. Seen in profile, they frequently divide near the ground into three or four upright, outward-curving trunks that carry short, stiff, lateral branches.

They can reach 10 m in height, but are normally much less. The new shoots grow in whorls (verticils) of three and emerge at an acute angle from the stem, giving the tree its characteristic asymmetry and crooked form.

Imbe trees are normally described as being dioecious (male and female flowers occurring on separate trees). Both sexes flower prolifically, and the quantities of pollen and nectar they produce attract large numbers of insects, which in turn attract large numbers of birds, making imbe trees a boon to the environment. As the season progresses the trees become loaded with ripe fruit and take on an even more exceptional appearance. Each fruit looks like a small plum: yellow-orange-red in color and round or ovoid in shape but it has a point at the bottom. The skin—thin, smooth, glossy, and leathery tough—separates easily from the flesh. The pulp itself is yellow and watery, with a pleasing flavor—sweet, and not unlike a perfect peach. In the center are one or two seeds which, unlike its relatives, are not reported as eaten.

On the downside, these seeds are about the size of small dates and are quite large in proportion to the overall fruit, making the pulp correspondingly thin. Also, the pulp clings to those stones in the center. In addition, unripe pulp can contain latex, which tends to stick to the consumer.

The fresh fruits are eaten raw or are commonly cooked with porridge and other cereal products. Once the seeds are removed, the flesh can be sun-dried and stored like a pitted prune. The fruit is also crushed like grapes to create a drink. Indeed, fermented beverages are sometimes prepared. One of these is a purplish, claret-like wine; another is a liqueur made by soaking the fruits in alcohol and thickening the extract with syrup.

NEXT STEPS

Africans, like people everywhere, value certain trees more than others, and superior trees are already well known in various locations. These offer opportunities for rapid horticultural advancement. Among the first things to be done, therefore, is to locate, identify, and compare these special types.

This process of genetic selection offers to considerably improve characters such as sweetness, appearance, rind toughness, pulp thickness, latex content, fruit size, seed size, and maybe freestone quality. It should be possible to increase the thickness of the pulp by seedling selection; likely they already exist. The culinary preferences of the local inhabitants also may have been subjected to selection, so superior types that reflect flavor and other local preferences may well be available. Precocity, prolificacy, tree size, and regularity of bearing are additional important horticultural attributes that likely have been selected for.

The key to turning imbe into a viable fruit crop lies in the vegetative cloning of select specimens. Both male and female specimens can be vegetatively propagated by air layering or grafting. Budding is probably feasible as well.

The small, orange-colored imbe provides a pulp that is juicy, pleasant, and sweet-to-acid on the tastebuds. East Africans have dubbed it "King of Fruits." Even those specimens that are unusually sour prove notably appealing on a hot and sweaty afternoon. (© TopTropicals.com)

There is also, however, the possibility that imbe is one of those rare plants that can clone itself through its own seeds (a process known in botany as apomixis). In various places several generations of trees grown from seed have yielded plants exactly like their parents…with no apparent variation among all the progeny. Also, it is said that female flowers that have been bagged (to keep all pollen out) can produce normal fruits and set viable seed.[3] This pollenless fruit production obviously has important implications for selection—some trees will produce apomictic seeds, which grow true-to-type, while other trees produce sexual seed, which express various gene blends. The apomixis would greatly aid selection and virtually guarantee clonal purity. In addition, male plants would not be needed in any planting

[3] Imbe's famed Asian cousin, the edible, cultivated mangosteen (*Garcinia mangostana* L.), is an obligate agamosperm (creating unfertilized, clonal embryos), which arose in cultivation and does not occur in the wild. Reproduction is entirely asexual. Fruits grow parthenocarpically on female trees, and seeds maintain trueness-to-type. Richards states that imbe is a probable facultative agamosperm. In other words, it is likely imbe reproduces both by apomixis (like mangosteen) *and/or* by normal sexual reproduction between male and female trees. Richards, A.J. 1990. Studies in *Garcinia*, Dioecious Tropical Forest Trees: Agamospermy. *Bot. J. Linn. Soc*. 103(3):233-250 (this is the first of three seminal articles detailing the long-mystifying origin of the Asian mangosteen).

(indeed, as in certain other species, males might be mere nuisances). Best of all, good types could be replicated via the simplest and cheapest method: planting seeds. Obviously, further research to clarify these aspects—which could rapidly open this crop to major new production with little fuss or fumbling—is urgently needed.

Virtually no research on the horticultural requirements has been done to date. In a sense, everything about cultivating imbe needs investigation. In particular, conventional vegetative propagation needs to be researched. Even if apomixis proves to be real, reliable, and practical, grafting onto selected rootstocks might still be beneficial. Other unknowns that need answering include: Is pollination sometimes necessary or beneficial? What are the optimal sex ratios in cultivated pollinating populations? How densely should the trees be planted? Should they be pruned? If so, when? And how?

It is known that the seeds germinate readily if they are fresh and are kept moist and warm. Also, the seedlings are said to transplant easily. The problem is that they subsequently grow too slowly for most people.[4] This slowness will likely be overcome by vegetative propagation, which is known to slash the time-to-first-flowering in many crops.[5]

Little is known about handling imbe fruits. The rather tender skin would seem to limit the possibility of shipping imbes long distances, but so many other fragile fruits are routinely transported across the oceans these days so it may be less of a limitation. In addition, the imbe deserves to be more widely cultivated as a backyard fruit, where the question of shipment is moot. This topic is clearly connected with the strength of the skin. Not all the fruits are thin skinned. Some have a thick hide, a genetic quality that could be most valuable and vastly change imbe's prospects.

Special areas for fascinating research into the greater use of this resource include the following.

Environmental Improvement The plant is surprisingly drought resistant and may find use in efforts to combat early stages of desertification. Yet another interesting environmental benefit deals with imbe's potential as a hedge. Although normally a tree, it can be planted close together and clipped to form a low and solid hedge. Given the dense and evergreen foliage, imbe hedges might find many uses. They might, for instance, be planted around fields and gardens. Imbe hedges planted on the contour across the hillslopes

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[4] "We've successfully grown *Garcinia livingstonei* and have many in the nursery but they don't sell because they're so slow growing. We keep on planting them though out of responsibility to future society. One day they'll be large and everyone will be wanting them. Fresh seeds germinate very easily in moist mulch but are not viable once they've dried out." Ray Perry.

[5] Even without vegetative propagation it could have a future. Imbe certainly grows faster than the true mangosteen, which begins rapid growth only after 5 to 7 years and fruits heavily only after 6 to 12 years and has nonetheless become a major crop in Asia.

may provide excellent edible erosion control. Similar close-spaced plantings could mark compound boundaries, pathways, property lines, and so forth. In such cases fruits could be a secondary product or at least a contribution to the diets of wandering children or animals.

Food Technology There is much potential for processing into fruit-based products such as juices and pulps. This needs exploration. The rind is rich in pectin, potentially making imbe an excellent ingredient for preserves, jams, and jellies.

Health Research Perhaps there are medicinal benefits to be gained from the imbe. Extracts of leaves and flowers apparently have antibiotic properties. The sap is said to be bactericidal.

Subbing for the King Imbe might also prove especially useful in extending mangosteen production to Africa. The two are so closely related that imbe is likely to provide a rootstock onto which its cousin can be grafted. This combination may have considerable commercial significance for extending the mangosteen's range beyond Asia and perhaps beyond the humid tropics. This would put mangosteen on the lips of millions who can now only dream of what the "world's most delicious fruit" must taste like.

Environmental Requirements

As to where imbe cultivation should be attempted, no one can be certain. Natural stands may or may not be a guide in this regard. However, based on those natural stands one might consider:

Temperature Despite an ability to survive light frost, this plant must be regarded as heat loving and likely to perform best in tropical lowlands and the hot subtropics. In cooler subtropical climates where, for example, the navel orange achieves best quality, the imbe grows too slowly to be commercially viable. In the lowveld as far south as KwaZulu-Natal, it typically occurs where mean annual temperature is 20-22.5°C and frost never occurs. This is the most southerly distribution of what is essentially a tropical tree.[6] In Botswana, imbe is fairly common around the huge inland delta known as the Okavango. Here, and to a lesser extent in Namibia's Caprivi Strip, light ground frosts occur during the coldest winter months, but winter days are warm and the summers extremely hot. Mature imbes are reported to withstand 7°C below freezing without serious injury.

[6] The immediate, low-lying coastal strip to approximately Durban is probably the southerly limit in terms of heat unit accumulation for satisfactory growth.

Soil Trees are found on sandy or dry rocky sites as well as in coastal areas. Soils vary from deep sands to heavy alluvial soils along riverbanks.

Moisture Although many grow beside rivers, on floodplains, or other locations with high watertables, others grow in fairly arid locales. It tolerates dry seasons as long as 5 months with ease and withstands fire as well. Like many arid and fire-resistant trees, these robust plants have a bulbous base underground. At the same time, the species grows satisfactorily in most soils

BITTER KOLA

Probably all the 400 *Garcinia* species have edible fruits. Among other African species worth research attention is *Garcinia kola*. Known in commerce as bitter kola,[7] this is a species of tropical West Africa, perhaps most famous in Sierra Leone. The pulp of the fruit is good, having a sweet/sour taste, but it is hardly known even where the tree is widely grown. Seeds are currently the important product, and are seen in markets from Senegal to southern Nigeria, Cameroon, and deep into the interior. They are chewed like cola nuts (the source of ingredients in drinks such as Coca-Cola® and Pepsi-Cola®). They are bitter, astringent, aromatic, and taste somewhat like coffee beans, followed by a slight sweetness.

A contributor in Ghana, Albert Adai Enti, urged this species' inclusion: "The <u>seed</u> of *Garcinia kola* is little known," he explained, "only because the amount sold in the markets is insignificant and many people do not notice it. In addition, the <u>wood</u> is a popular chewstick, which is used mostly to clean the teeth. It is sold everywhere and used by almost everybody. So people hardly allow the tree to grow to fruiting age before they cut it. The result is that only a few trees, fortunately hiding in remote areas, are able to fruit but cannot produce enough to meet commercial demand.

"So although the seed is a good chewable food, it has never been popular. At present, *Cola nitida*, the true kola, is the most popular chewed seed, which is also meeting commercial demand for export. But if *Garcinia kola* can be established in plantations and protected, the fruits will certainly be produced and used in the same way as *Cola nitida*. It is a rainforest tree species and the seed germinates well. It may be slow growing but will grow by all means if left undisturbed. I am sure it could be an economic fruit tree once established and controlled."

Adding to this species' potential is the fact that Africans use the small branches every day as disposable toothbrushes. The twigs have recently been shown to contain antiseptics, and thus seem likely able to maintain healthy teeth and gums. The seeds are also added to palm wine to make it "stronger" in its effects.

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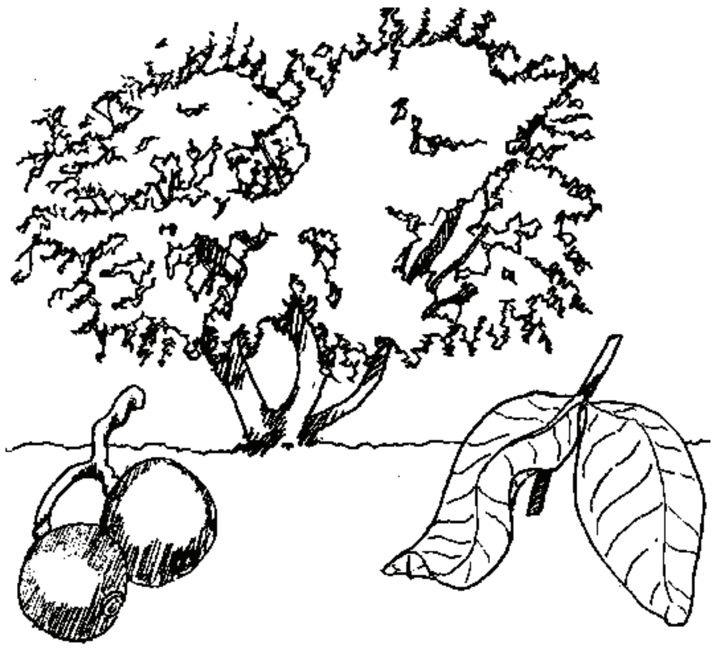
[7] It is also called false kola, kola male, or kola bitter.

This plant is a highly valued ingredient in African traditional medicine. Throughout West Africa it has been employed in folk medicine as rejuvenating agent and general antidote. Confirmatory discoveries have recently been made by researchers working in prestigious medical research facilities in the United States and elsewhere. In this work, bitter kola seeds have been shown to contain a complex mixture of biflavonoids, benzophenones, and xanthones. The biflavonoids have demonstrated many pharmacological effects, among them antiviral, anti-inflammatory, antidiabetic, bronchodilator, and antihepatotoxic properties. The benzophenones showed antimicrobial activity in other studies. Some proprietary dietary supplements containing *Garcinia kola* extractives already exist in African and Western markets.

Among the myriad African *Garcinia* species, a sampling of the "best known" includes:

Garcinia afzelii West tropical Africa, fruits chewed like cola.
Garcinia buchananii Tropical Africa.
Garcinia buchneri Southern tropical Africa.
Garcinia cernua Voahandrintsahona. Madagascar.
Garcinia conrauana Southern tropical Africa.
Garcinia gerrardii Umbini. Large shrub of Natal and adjacent territory. The fruits are orange, ovoid, and big (up to 2.5 cm long).
Garcinia huillensis Yellow plum-like fruits; juicy yellow flesh.
Garcinia kingaensis Excellent fruits, but very acid.
Garcinia ovalifolia Tropical Africa.
Garcinia polyantha Tropical Africa.
Garcinia wentzeliana Mogola. This woody climber of tropical Africa, bears sweet, juicy, agreeable fruits that look like grapes.



9

MEDLARS

In eastern, central, and southern Africa, at least eight species of *Vangueria* are commonly found growing with vigor in dry, eroded, infertile, leached, or otherwise challenging sites. These trees closely resemble one another in both appearance and a propensity to bear lots of fruits. Specimens with as many as 1,800 fruits have been recorded and, given a street value of 4 cents each (U.S. currency, as recorded from Botswana), that amounts to a harvest worth more than $70 a tree.

With their unusual but appealing flavor and aroma, these fruits are described as being akin to dried apple. Although of apricot size, the fresh fruits resemble the European medlar (*Mespilus germanica*) in color and appearance. In many parts of Africa they are eaten and enjoyed like medlars…raw, roasted, and dried. A renowned and potent gin (known in Afrikaans as mampoer) is distilled from their fermented pulp. Indeed, they are so all-round popular that farmers from South Africa to Sudan and Senegal carefully preserve the trees when clearing land to make fields.

Despite the widespread enthusiasm, little was done to explore the economic potential or horticultural development of these species until quite recently. They were thought to grow slowly and yield too little to be worth the bother. Now a few brave pioneers are discovering that at least one member of this African fruit genus is relatively fast growing and has good potential for domestication.

For the moment, though, a horticultural industry based on African medlars is a long way off. Wild stands are likely to remain the predominant source of fruits for some time to come. This is unfortunate because the fruits of most of those trees are more seed than flesh. It is misleading to judge the ultimate promise by present appearances. The current types are unselected, and some are wasted and withered because they come from trees that are stressed from the difficult sites they grow on.

As these trees are made increasingly user-friendly they could contribute much to rural Africa. Although seeds fill most of the space inside most of the fruits, the pulp-to-seed ratio is very variable. Where the trees are reasonably well watered and benefit from good soils (which is far from frequent nowadays), the fruits are larger and can have a huge proportion of flesh. Fruits of the best-known medlar (*Vangueria infausta*) have been

The mealy fig-like flesh of the African medlar is sweet and refreshing and tastes somewhat like apple. It is an important and popular food. In fresh form it lasts barely a week, but in dried form it can keep for almost a year. Although still undomesticated, the fruit has much potential for horticultural development. (Rihana Botha, www.ecoport.org)

measured having 60 percent flesh, sometimes 80 percent in Botswana. This is a clear indication that careful selection of site and seed can alone transform this crop.

The trees' immediate potential is probably not production in orchards but in back gardens, spare patches of hillside, village greens, or verges of roads, tracks, and rivers. In agroforestry they could find a notable niche. Already several species are used as hedge plants to demarcate fields and farms.

Even when ripe, their fruits refuse to fall, and must necessarily be picked. Although the fruits may stay aloft on the branches for up to a couple of years, by then they are usually useless. However, for maybe six months they remain edible, which can provide a handy food-store in times of need.

The fruits are promising in commerce. Marketable products include whole or dried fruit. Unprocessed or processed, they are potentially useful as nutritional supplements (in, for instance, the widely popular sour-tasting fermented porridge). They are also sold as a flavoring agent and for producing alcoholic beverages.

A special feature is the easy desiccation. The fruits can be sundried, stored, and then eaten months later. After soaking in cold water for 12 hours or in warm water for less, the reconstituted fruit tastes almost like new. Because of this, they are commonly stored in dried form and used in times of scarcity, such as during the winter months. Typically, they are then boiled in

water and the resulting liquid is then used to flavor other foods, notably mealies (maize porridge).

Undoubtedly, though, they contribute more than just flavor. One African medlar's vitamin C content, for instance, is said to be 3.7 mg per 100 g.[1] However, other species are said to contain no vitamin C, and analytical chemists could perform a signal service by analyzing representative samples of African medlars fruits to determine their full nutritional qualities.

Like so many of the other plants highlighted in this book, the African medlars provide more than one food. In this case, the kernels of the seeds are also eaten. And there are non-food uses, too. The wood, roots, and leaves have medicinal uses.[2] Perhaps because of this, there is considerable positive superstition associated with these trees. Across southern Africa, for instance, local lore has it that a beneficent *Vangueria infausta* bears fruits heavily just before a big drought.[3] And in Swaziland, stakes or pegs from the wood are used to ward off lightning.

Individuals interested in helping different parts of Africa should investigate the local *Vangueria* species and genotypes, not to mention the many and varied local methods of handling and preparing the different fruits. Taken overall, these plants offer great projects for students, anthropologists, botanists, plants persons of varying levels of experience, and Africanists of perhaps every type. Pooling the Africa-wide knowledge and the best insights of science will likely catalyze even greater levels of activity and thereby arouse not only greater appreciation for this indigenous resource but also open the doors to a new and vibrant horticultural industry.

Documenting traditional usages together with exploratory nutrition research and feeding trials should be the first steps. As these plants are already well known to millions, information on local traditional usages will enable a fair assessment of the plant's true value. The nutrition research and feeding trials will complement the information on local uses. Not until the real importance becomes known should other major research and development thrusts be undertaken. If the preliminary findings are good it should be easy to carry out awareness campaigns leading to and resulting in marketing and economic development.[4]

There are reports of a surprising number of medicinal uses, which, given the state of healthcare in Africa, might open another pathway to progress for these resources.[5]

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[1] Watt and Breyer-Brandwijk, 1962. *Medicinal and Poisonous Plants of Southern and Eastern Africa*. Livingstone, Edinburgh and London.

[2] Roots are used, for instance, as antimalarials and to treat pneumonia. Crushed, soaked leaves are said to bring down swellings and to be good for treating styes in the eyes.

[3] Whereas trees cannot possibly foretell the future, one of our contributors noted the coincidence that the trees in his neighborhood did exactly that 1981, a year that was followed by a terrible eight-year dry spell.

[4] Ideas from Nat and Patricia Quansah, Madagascar.

[5] See, for example, Venter, F. and J. Venter. 1996. *Making the Most of Indigenous Trees*,

Promising species include the following:

***Vangueria infausta* Burch.**[6]

This shrub or small tree occurs in abundance in woodlands, scrub, valleys, stony kopjies, or sandy dunes throughout much of South Africa (Transkei and Gauteng, for instance), Swaziland, Botswana, Namibia, Zimbabwe, Mozambique, and Malawi. It reaches 6 m tall, with a fluted cylindrical trunk and a spreading, somewhat rounded crown.

When ripe, the fruits are spherical, shiny, and yellow or light- to reddish-brown. They come crowned with the remains of the calyx. The leathery skin easily peels away to expose the pulp and seeds (usually three) inside. The fruits themselves look somewhat like dried pears, and their sweet-acid flavor is much liked. Mixed with a little sugar and water, the pulp produces a good substitute for applesauce; many farm families use it in puddings.

This is a species for which domestication projects are underway. One is that of Veld Products Research in Gaberone, Botswana. Its researchers turned for help to Botswana's children; co-opting the kids' expertise to find which trees produced the best fruits and providing prizes for the best seeds. The kids proved to really know the plants. Some seedlings from their favorite trees produced fruit at the almost incredibly early age of 8 months; at 2 years of age (and only 1.3 m tall) they bore as many as 400 fruits.[7]

In this and other programs, encouraging responses to grafting have also been observed. In some cases grafted trees have been found to grow up to twice as fast as the ungrafted seedlings and to yield as many as 1,500 fruits. Some of those fruits were as big as 15 cm in diameter, an almost unimaginable size to those who've seen only the wild fruits.

The researchers domesticating *Vangueria infausta* in Botswana have run into potential problems, however. First, they've found that drought or erratic rainfall causes fruits to abort, a problem easily overcome by supplemental irrigation (if it is available—and if it is not commandeered for something like mangoes). Second, a mite causes galls on the leaves and if the trees are grown at high density it can spread easily and quickly and affect overall

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Briza Publishers, Pretoria.

[6] A synonym is *Vangueria tomentosa*. Lacking any other common English name, these fruits are called wild medlar, or African medlar. Local names for this species and its fruit include mmilo (Pedi, Sotho, Tswana), umviyo and umvilo (Zulu), mispel, mobilo, and matugongo, umntulu (siSwati), mmilo (sePedi), and umviyo (isiZulu).

[7] In Malawi, similar spectacular growth and production have been obtained. Maghembe, J.A., 1995. Achievements in the establishment of indigenous fruit trees of the miombo woodlands of southern Africa. Pp. 39-49 in Maghembe, J.A., Y. Ntupanyama, and P.W. Chirwa, eds., *Improvement of Indigenous Fruit Trees of the Miombo Woodlands of Southern Africa. Proceedings of a Conference, January 23-27, 1994*, Mangochi, Malawi. International Centre for Research in Agroforestry, Nairobi.

production. Third, the tree's leaves are attacked by fungus, although there seems to be little effect on the production of fruit.

In this research, it has been found that the seedlings need the help of beneficial fungi. Most of the specimens examined in the field have formed symbioses with these helpful microbes (arbuscular mycorrhizae), which aid in the plant's establishment, survival, growth, and productivity. They are now working on ways to ensure that the seedlings in the nursery have this beneficial infection on their roots.[8]

Food technologists in South Africa have also run into problems. "We have found," writes our contributor Cori Ham, "that there is so little juice in the fruit that it is very difficult to work with when making nectar and fruit rolls. The nectar has a brown color and cinnamon-like taste and our consumer panel rejected it on the basis of its unpleasing color and thick consistency. It had however very high sugar levels and the potential for blending it with other fruits should be investigated."

Vangueria madagascariensis J Gmelin[9]

This species is native to Mozambique, Madagascar, and the Indian Ocean islands of Mauritius and Réunion. Its somewhat apple-like fruits are borne in clusters of two to five. They are nearly round and sized like golf balls (3.5 cm diameter), with smooth tough skin and whitish flesh, turning brown when fully ripe. The flavor has been likened to "a blend of apple and tamarind." The fruits sell well in the produce markets of Uganda, Kenya, Madagascar, and elsewhere. They are eaten raw, stewed, or roasted.

Even on Madagascar itself, little has been done to develop this much-enjoyed fruit. Artificial regeneration has not been tried, and there are no orchards. The crop is, however, semi-cultivated on farms. People clearing land for farming always leave these trees as future sources of fruits. The tree is variously associated with magic and witchcraft and cattle fertility and so it is not cut down nor is its wood burned.

Germination is said to be difficult, owing to the hard seedcoat. However, it cannot be too difficult, because the plant is grown to a small extent in Bangladesh, the Philippines, Puerto Rico, the Virgin Islands, Martinique, and Trinidad and Tobago.

Improved methods of propagation and horticulture could help boost the income of fruit growers, especially if the marketing of fruits can be better organized. And beyond that, this forest-dwelling species holds promise for helping Madagascar's beleaguered and fast-disappearing rainforests. The tree will grow in dry regions but bears best where there is plenty of year-

[8] This is of course a means for benefiting not just this species but most or all of the others in this book as well.

[9] Synonyms are *Vangueria edulis, Vangueria acutiloba,* and *Vangueria venosa*. Common names include voa-vanga and Spanish tamarind.

round precipitation. It has good potential for contributing to "supply-side" conservation. Organized harvesting of such forest fruits would help give local people a stake in keeping the forests standing. Some use might be found for the seeds, which, apparently, have received no attention. At present, however, the species is not regenerating adequately.

Vangueria apiculata K. Schum.

This eastern African species, often called shikomoli, is common to all parts of Uganda and is found as far south as eastern Zimbabwe. It, too, occurs in scrubland and forests and is typically a shrub or tree to 12 m or more. Its fruit is fleshy and 2-3 cm wide. It is produced in abundance and is commonly eaten. The pulp around the seed is thin but sweet. The root is employed to treat roundworm.

Vangueriopsis lanciflora (Hiern) Robyns[10]

This fruit of a closely related genus is reported to be the tastiest African medlar of them all.[11] It comes from a species found notably in Zimbabwe. It grows as a bush up to 3 m high in the southern part of the country and a tree up to 12 m tall in northern part. The fruits look like oblong, yellow plums. They are similar to the main African medlar (*Vangueria infausta*), but can be both smaller and slightly larger. The pulp is crumbly, but the skin is tough and the pulp is easily squeezed right out into the mouth. Only one or two seeds occur in these fruits.

This species is in need of genetic selection. Whereas most of the fruits are exceptionally flavorful, some are reported to be tasteless. Undoubtedly, this is due to genetic differences between the trees. Vegetative propagation of superior types might quickly make this into a winner. The plant is grown from branches "stuck in the ground." These apparently take root readily, so the cloning of great-tasting types should be easy.

Lagynias lasiantha (Sond.) Bullock[12]

Another fruit-bearing tree from a closely related genus, this species is said to produce fruits "as good, if not better than *Vangueria*."[13] Native to tropical East and southern Africa, the fruits of this shrub are undoubtedly pleasant to eat and should be more widely enjoyed.

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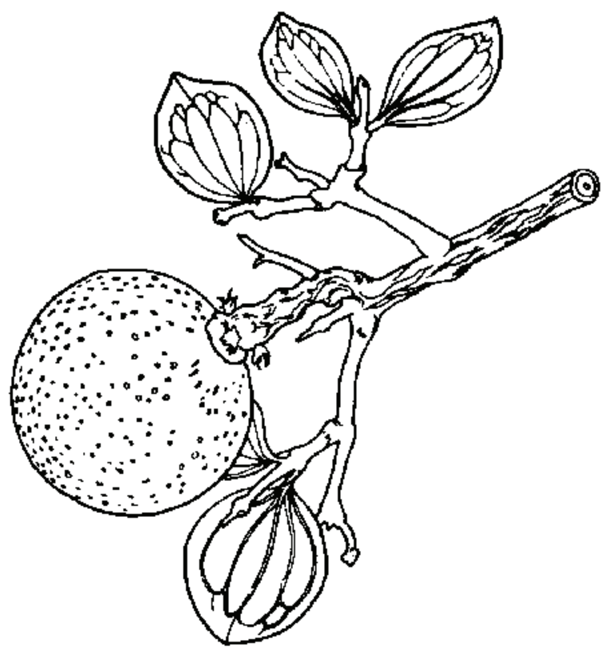
[10] Often called Zimbabwe wild medlar, mutufu, umyiyo, mufilu (Bembe), msoli (Nyanja), musole (Tonga).

[11] When we asked about dropping certain species from our first draft one contributor wrote back: "Please keep *V. lanciflora*—it is yummy!!"

[12] Known in South Africa as the umtulu tree.

[13] Information from A. B. Cunningham.

Vangueria esculenta



Strychnos cocculoides

10

MONKEY ORANGES

Although perhaps more than 20 *Strychnos* species produce edible fruits in various parts of Africa, three stand out. *Strychnos cocculoides*, *S. spinosa,* and *S. pungens* produce large, pleasantly flavored fruits that are easy to handle and often in short supply. Farmers appreciate the trees so much that when clearing land they spare them the ax—even if plowing or planting field crops will be awkward. These three special monkey orange trees are widely enjoyed and have the amazing capacity to stay edible in tropical heat for months after maturity. This is important for food security: monkey orange has been called, "A great and precious resource in times of crop failure."

Of all Africa's native fruits, these are perhaps the most "conventional." They are similar in size and shape to apple, pear, and orange trees. Given horticultural attention, they probably can be raised with equal facility. There have other advantages, too. They bear fruit in abundance. They make excellent additions to gardens, parks, streets, and fence lines, by providing not only food but also shade, shelter, and erosion protection.

Above all, though, these fruits provide a profit. Indeed, they sell at very high prices and still the full demand is seldom met. A much greater commerce in monkey fruits is eminently possible. Even an export trade is not beyond question. Zimbabwe has already exported some of the fruits to Botswana, and that could be just the beginning.

High prices, high productivity, great shelf life, unmet demand…these are the makings of success in any fruit. However, few people have attempted to produce monkey oranges in organized cultivation. For all intents and purposes, they remain unknown to horticulture, and remain undomesticated.

Clearly, these three special monkey orange trees warrant intensive research and development. And that has begun…at least in a modest way. In southern Africa, selection and cultivation of monkey oranges is underway, in hopes these plants may eventually be grown intensively. Beyond the possibility of orchards, however, is the promise of improving production from the wild resource and expanding monkey orange trade within and among African nations. These fruits may find a home beyond Africa as well.

One species grown in Israel is already showing enough promise for optimism about its future as a crop.[1]

In these three special *Strychnos* species, fruits tend to be yellow, orange, or brown in color and about the size of grapefruits. They are marketable size and quite stunning to the eye. They typically store and ship far better than most fruits. Indeed, they can be piled in the open for storage because their hard, gourd-like shell resists not only fungi but also fruit flies. Some are even buried several months, and (as long as the shell has no cracks) they come out of the ground juicy and golden ready for dessert.[2]

The yellow or brownish pulp inside the fruit surrounds a number of scattered but conspicuous seeds. To eat a fresh monkey orange you simply suck the juicy flesh from around those seeds.

A particular problem with some *Strychnos* species is that, although the ripe pulp is safe to eat in moderation, eating too much at one time can be purgative. In addition, care must be taken not to chew the seeds of most (but not all) the species. Those smooth and shiny seeds, as well as the bark and roots, contain strychnine and may produce vomiting or headaches. Their slippery nature makes them easy to swallow accidentally, but they pass through the body safely without causing harm. **However, in extreme cases, after chewing irresponsibly the bitterest seeds, even death may occur.** These facts are widely known where these trees occur, and at least in *Strychnos pungens* not even the seeds seem to contain toxins.

Although high prices, high productivity, and great shelf life make for success in any fruit, capitalizing on that promise in an organized way requires that much more be done. The priorities for domestication given in other chapters are also relevant with monkey oranges. The goal should be high and consistent yields of large, good quality fruits. And that requires technical advances such as selection, vegetative propagation, and proper management of the plants. This seems certainly achievable; however, monkey oranges have some special research needs, including:

- Selection of trees with minimal levels of harmful alkaloids (strychnine, bruisine) in the seeds and skins.
- Artificial defoliation to synchronize the fruit formation and allow orchardists to harvest the entire crop at once.
- Hybridization between species to explore the possibility of wholly new and perhaps exceptional fruits, al la nectarine or plumcot. This is a speculative notion, but *Strychnos pungens* is known to hybridize with *S. innocua*, so the possibility of shared genes and perhaps of seedless fruits is far from impossible.

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[1] Information from Y. Mizrahi.

[2] An exception appears to be *Strychnos spinosa*, which cannot be stored for long, especially under tropical heat and humidity, perhaps because of higher fat levels.

Stychnos cocculoides, Congo D.R. Fruits of this and the other three special monkey orange species are of marketable size and quite stunning to see. Not only are they large, flavorful, and easy to handle, they are often desperately difficult to find due to overwhelming demand. (Paul Latham)

Contributor P. du Plessis summed up the overall situation: "*Strychnos* fruits are very popular and seldom available in surplus quantities because of an extensive local and regional trade," he wrote on a draft. "New plantings are urgently needed to make available fruits for export markets and for processing. This should be done in Africa with Africans."

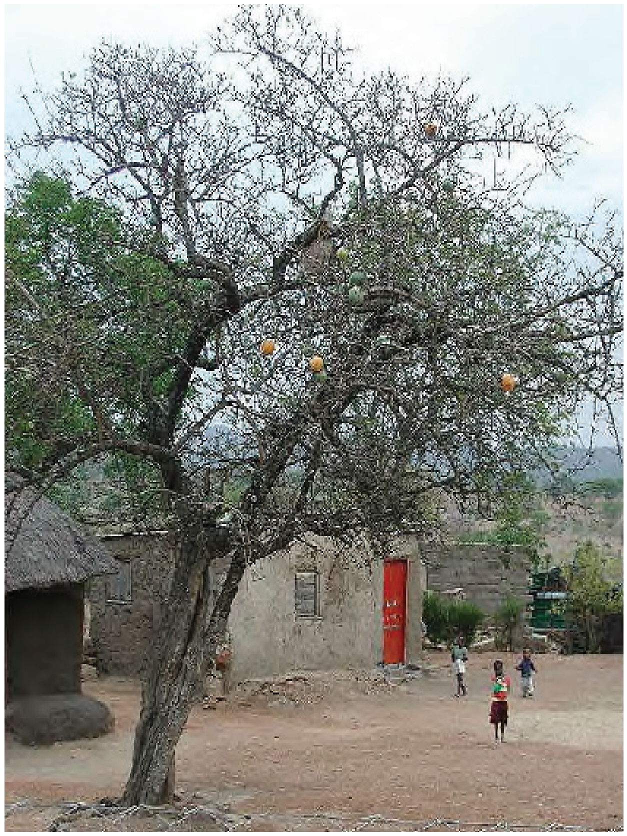
These three promising species are highlighted below.

Corky-Bark Monkey Orange (*Strychnos cocculoides* Baker)[3]

This compact tree 2-8 m tall (occasionally reaching 10 m) of the Kalahari and its surrounding savannas and dry woodlands is found on sandy soils and rocky slopes in Botswana, northern Namibia, and parts of Zimbabwe and South Africa.[4] It bears round fruits 6-10 cm in diameter, with hard, woody, brittle shells. When immature they look like avocados. They fall from the tree before they ripen. As they mature the thick shell turns orange, at which

[3] The tree derives its name from the characteristic corky bark, deeply ridged longitudinally. It is also known as suurklapper (Afrikaans). Much additional information on this species is available in Mwamba, C.K. 2006. Monkey Orange *(Strychnos cocculoides)*. Fruits for the Future 8. International Centre for Underutilised Crops, Southampton, UK; see icuc-iwmi.org.

[4] Notably the bushveld of Gauteng (western Transvaal).



Green monkey orange, Luphisis village, South Africa. The trees that yield monkey oranges make excellent additions to gardens, parks, streets, and fencelines—providing not only food but also shade, shelter, and erosion protection. However, fruits from these unselected trees can be disappointing as food. (Claus Lipis)

point it can be broken open and the yellow or brownish pulp scooped out. The pulp is very refreshing, and its taste has been variously described as "a combination of citrus and pineapple" or "a mixture of citrus and banana." It is much beloved. Kung people walk for days to find trees that are bearing, and fruits are widely sold in traditional markets throughout the area. They are sold, for example, in Bulawayo, Zimbabwe from September to October.

In nature, the species regenerates by seed, coppice, and root suckers. The seed has a hard coat and resists easy germination. Undoubtedly, scarification techniques can be found to promote quick and uniform sprouting.[5]

[5] Indeed, one of our contributors in Zimbabwe wrote: "I have had no trouble germinating

In a pioneering program in Botswana, a small organization devoted to the development of wild African plant resources has made remarkable progress with improving this plant's overall productivity. Researchers at Veld Products Research applied horticultural techniques to six superior phenotypes they obtained from the wild. Even before receiving horticultural attention those select 6 averaged between 300 to 400 fruits per tree, each fruit averaging 10 cm in diameter and a third of a kilo in weight. Those may seem like exceptional trees, but given some fertilizer and appropriate watering the fruit size rose to 15 cm diameter, the maximum production to 700 fruits per tree, and the weight to over half a kilo per fruit. Street value of each fruit (before improvement) was 40 cents in U.S. currency, so a single tree producing 700 fruits could bring in gross income of well over $200.

In these trials, propagation by seed has been successful; in the nursery 80 percent germination within 3 weeks has been recorded on seeds sown in summer. (Those sown in winter took more than 9 weeks.) The plants also responded well to inorganic fertilizers.[6] In field plantings at Gabane, Botswana seedlings treated with superphosphate and blood- and bone-meal (Nitrosol®) fertilizers doubled their heights (to an average of 76 cm) within 13 months, while those untreated remained below 20 cm for 3 years.

Encouraging responses to grafting were also obtained. In some cases the grafted trees grew twice as fast as the ungrafted ones. They also tended to yield fruits within 3 years of transplanting. The ungrafted seedlings, on the other hand, took 4 to 5 years to bear any fruit.[7]

Green Monkey Orange (*Strychnos spinosa* Lam.)[8]

This small thorny shrub or small tree (6-10 m) is very similar to corky-bark monkey orange. It is, however, found more broadly throughout the drier parts of Africa: from Senegal to southern Ethiopia, and from there to the eastern seaboard of South Africa. It is a variable species, its genetic divergence being so great that three subspecies have been recognized. It is widely spread across dry tropical to subtropical savannas, open woodland, river fringes, and mountain slopes up to about 2,000 m. Although home in hot, dry tropical or subtropical savannas, it tolerates light frost.

The spherical fruits—sometimes as large as a quince (15 cm in diameter)—are bright green when immature, but turn yellow when they fall, and then brown or black. They have been called "one of the best native

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seed from old, open fruit (presumably opened by baboons), which was thoroughly dried."

[6] Not all responded; some, for reasons unknown, stayed short and refused to flower.

[7] In Zambia, however, there are reports of trees raised from seeds yielding fruits within 3 years of transplanting. Information from C. Mwamba.

[8] Also known as Natal orange, monkey ball, monkey apple, elephant orange, spiny monkey orange, amahlala (Zulu), klapper, and other names. Its smooth (rather than corky ridged) branchlets help distinguish it from the very similar *Strychnos cocculoides*.

fruits," and are, for instance, one of the favorites of Mozambique, where they sell well in the markets of Maputo.

The skin of the fruit is so hard it must be physically cracked open, but the pulp then comes out as a whole. It is whitish, yellow, light tan, or dark brown in color, and in flavor can be either acid or very sweet and delicate. On the tongue it can be jelly-like or juicy, and the taste is described as "somewhat like a lightly fermented tart apple, with a cinnamon-like odor that intensifies on cooking." Although mostly eaten fresh, the pulp is used in many other ways. In Madagascar, for example, it is often cooked with cereals to form a sweet porridge or it is dissolved in water to create sweet and tasty drinks. These latter are also fermented to an alcoholic beverage.

Little is known about nutritional value, but monkey oranges are reportedly rich in B vitamins and vitamin C. Tartness, as in lemons, derives from citric acid. One analysis in Malawi found it to be the highest in fat (31 percent) and energy (460 calories per 100 g) of 16 wild fruits tested, although these levels may be exceptional or anomalous, as the fruit is not normally considered oily.[9]

Two basic fruiting forms of this tree are distinguished. One, the so-called sweet type, has sugar-rich fruits clustered on short stalks. The other, the so-called bitter type, has long stalks, narrower leaves, and fruits that remain bitter when ripe.

Although slow growing, the tree is not difficult to plant and manage, and it seems to adapt well to many types of locations.[10] A well-drained soil is preferred and, despite a reputation for needing more water than other "lowveld" trees, this is a drought tolerant species. In some cases, the fruits may take several months or even a year to pass from flowering to full ripeness. They are so strongly attached that they must be cut from the trees with a knife or scissors.[11] But when ripe, they fall off on their own, especially if coaxed by someone shaking the tree. The shells remain whole unless they hit something as hard as a rock, tree trunk, or each other.

The seeds and bark contain strychnine and are best regarded as poisonous, although authorities differ on this point. The unripe flesh is said to cause vomiting. The rind is very bitter in taste and is to be avoided. The wood is white and is sometimes used for fence posts.

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[9] Saka, J.D.K., J.D. Msonthi, and J.A. Maghembe. 1994. Nutritional value of edible fruits of indigenous wild trees of Malawi. *Forest Ecology and Management* 64:245-248.

[10] It has, for instance, been planted as a curiosity in Florida. It was introduced into Puerto Rico and Florida by the U.S. Department of Agriculture in 1921, and also into the Philippines at about the same time.

[11] Pulling them off damages the tree.

Spiny-Leafed Monkey Orange (*Strychnos pungens* Soler.)[12]

A small brittle tree, usually less than 7 m tall, this monkey orange is found from northern South Africa to Angola, Congo, and Tanzania. It often occurs where light frosts are far from unknown in winter. The fruit is round, 10-12.5 cm in diameter, and weighs as much as almost half a kilo. Like other monkey oranges, it has a woody shell, which turns from bluish-green to yellow as it ripens. The pulp is juicy, butter yellow, and has a somewhat rank odor. Although opinions about this fruit differ, some trees produce what are generally considered pleasingly fragrant and pleasant tasting fruits. The presence of citric acid makes them thirst quenching.

Alkaloids are supposedly absent in the seeds of this monkey orange. This should be confirmed. The seeds are very bitter, and if consumed in quantity may cause diarrhea.

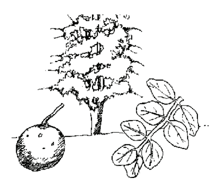
Perhaps a more serious concern is the competition people face in trying to get these fruits. Not for nothing are they named monkey oranges. Indeed, the fruits are eagerly sought by monkeys, as well as by forest antelopes, or even by both together. In Natal, for instance, the miniature antelopes known as duikers commonly search under a tree for flesh enclosed seeds being dropped by careless monkeys.

The whitish colored wood is hard and straight. It is much prized, especially by Zulus, who use the wood of coppice shoots for walking and fighting sticks.

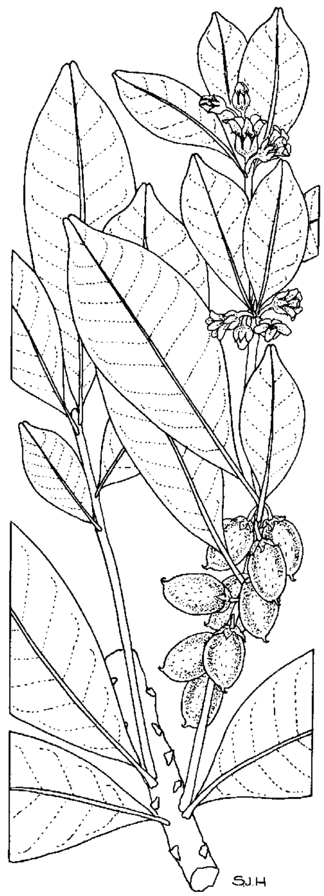
The species is very similar to *Strychnos spinosa*, and (in the absence of flowers) is distinguished by the blue-green color of the immature fruits as well as by small variations in leaf color, shape, and venation.

Like other *Strychnos* species, this is one tough plant. It thrives from sea level to high altitude. It is to be seen in woodland, wooded grassland, and urban settings. It occurs commonly in stony places or at the base of rocky outcrops (kopjies), not to mention deep sandy soils and open woodland, riverine fringes, and coastal forests. In the harshest sites it is commonly reduced to a small shrubby shadow of itself, with many stems sprouting from the base.

The seed germinates readily and reportedly the plants grow fairly fast.



[12] Also known as wild orange, black monkey orange, swart klapper, botter klapper, shiny-leaved mukwakwa, and other names. According to some botanical authorities, *Strychnos madagascariensis* is a synonym for *Strychnos innocua* (or at least of *Strychnos innocua* subspecies *dysophylla* and subspecies *gerrardi*).



Bequaertiodendron natalense

11

STAR APPLES

Two common dooryard trees in tropical American countries are the star apple (*Chrysophyllum cainito*) and satinleaf (*C. oliviforme*). Everybody loves having them grow near the house. Their leaves are deep green on top and have a satiny coat of golden brown shiny hairs underneath. Wind rustling the foliage creates a striking effect as the green and gold flash sequentially in the sunlight.[1] In addition, these beautiful trees produce some of the most beloved local fruits. Their apple-sized delights have a sweet flesh with small seeds arranged in a typical star pattern.

Both trees are widely planted in the Americas. They grow rapidly, often rising more than a meter each growing season. Once established, they become almost trouble free, resisting among other things pests, diseases, and high winds. As long as they remain unexposed to freezing temperatures, they burden the grower with almost no problems and continue to produce quantities of delicious fruit year after year.

What is not well known is that Africa has its own counterparts. The vastnesses below the Sahara contains more than a dozen species related to the American star apple and satinleaf.[2] These too are attractive trees producing delicious fruits. They also are candidates for producing trouble-free dooryard delights, and perhaps more. But these African relatives remain horticulturally undeveloped and their nutritional qualities are not yet clear.

Despite neglect, Africa's star apples are esteemed in many places. The fruits are green, purple, apricot, yellow, or copper in color. Their smooth skin encloses a white, sweet-tasting pulp arranged in segments. Cut transversely, most of them display the family crest: the star-shaped arrangement of seeds. The pleasantly acid pulp is almost always eaten fresh.

Clearly, the various African species deserve at least preliminary horticultural and nutritional investigation. An overarching requirement for

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[1] For this reason, star apple is also called golden leaf tree. Victorian novelist Charles Kingsley described it as, "like an evergreen peach, shedding from the underside of every leaf a golden light—call it not shade? A star apple."

[2] Some botanists divide African star apples among different genera: *Chrysophyllum*, *Bequaertiodendron*, and *Manilkara*. *Gambeya* is a synonym sometimes used for *Chrysophyllum* (especially in the tropical-wood trade). Family: Sapotaceae.

Equateur Province, Congo D.R. Despite the fact that African star apples are currently unexplored and their value in organized plantings untried, they hold promise. They produce delicious fruits that are popular wherever they are grown. Selecting elite cultivars could create new consumers both locally and in far-away places. (Roy Danforth and Paul Noren)

greater progress is genetic selection. A huge diversity of different types exists. Fruits can be found, for instance, in an array of colors, shapes, sizes, and tastes. The trees also exhibit differing sizes, forms, features, and productivities. Some trees, for example, fruit heavily, others lightly. Little of this genetic wealth has been evaluated or even explored, let alone exploited.

Although named varieties and organized production are now unknown, superior plants are to be found and almost certainly can be propagated vegetatively. This needs doing. Elite clones will likely transform this wild crop by raising quality and reliability as well as by yielding fruits at a much younger age. Budgrafting white star apple, for example, has produced fruiting within 3 years in Nigeria.[3]

When superior fruits become available they seem likely to find ready outlets in both subsistence and commerce. However, at present not even the basics of production and use are well described. Little is known, for example, about the management of the trees, let alone the nutritional qualities of the fruits. Probably, though, the nutritional composition is not too different from those in American star apple, which is much like that of citrus fruit, except for the vitamin C which is less than half that in oranges.

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[3] Information from J.C. Okafor. Other vegetative methods likely to succeed are air-layering (marcotting), cuttings, and tongue-inarching.

One particular problem is that the fruits must be allowed to ripen on the tree; when picked immature they are sticky with latex and astringent to the palate. Today, they are allowed to ripen and fall, and are then picked up from the ground. It seems likely that this process can be improved upon. Probably, fruits can be picked immature and subsequently ripened using ethylene—a gas now widely used to ripen oranges, tomatoes, and other fruit on demand. This would extend the shelf life as well as the distance they could be shipped to market.

For their ornamental value alone these trees merit attention. They might make useful reforestation species as well. Fully grown, they reach up to 30 m in height and 2 m in girth, and their hard, white wood is famous for quality. It is in international demand, and is traded under the name longhi (or longui). One website touts it for "interior joinery, furniture components, domestic flooring, stairs, decorative sliced veneers, plywood, interior fittings, turnery, construction, vehicle bodies, handles, sporting goods, carvings, agricultural implements."

Particularly promising for investigation are the following:

White Star Apple

This forest tree (*Chrysophyllum albidum* G. Don) is native across much of tropical Africa. In recent times, however, it has sadly become uncommon in the wild. Today, it occurs mostly in villages, where it tends to exist as solitary specimens. In southern Nigeria and other areas of West Africa, such household plantings are the only remnants of what was once a common forest occupant. In those villages, however, the people look after the tree, commonly managing it in at least a rough-and-ready manner.

During the harvest season the fruits are put on sale, but mostly only in nearby villages; seldom are they shipped even to the cities. That is a pity because this fleshy, juicy fruit is wildly popular. It is nearly spherical, slightly pointed at the tip. When ripe, it is orange-red, yellow, or yellow-brown in color, sometimes with brownish speckles. Inside is a yellowish pulp surrounding five brown seeds arranged in the regular star shape.

To eat the fruit people first split it open, usually by squeezing it between the fingers of both hands. This exposes the pulp, which is commonly the color of flesh and tears apart not unlike meat. This very tasty fruit flesh is eaten directly, but only after any milky sticky juice has dripped away. It is said to have potential as a soft-drink flavoring. It is even now fermented into wine and sometimes distilled into spirits. High in pectin, it forms an excellent jam, said to have a shelf life of up to a year even in the tropics.

In some areas the white star apple is exclusively a food of children, some of whom prefer to chew the immature fruit, which at that stage is like gum.[4]

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[4] This is not as unusual as might at first appear. These fruits are part of the same family

Fruits of white star apple (*Chrysophyllum albidum*). African star apples remain horticulturally undeveloped and their nutritional qualities are undocumented. Despite scientific neglect, however, they are esteemed in many places, are likely to have nutritional merit of at least a modest nature, and good selections undoubtedly await recognition among its vast genetic diversity.
(J.D. Mollon/Petroc Sumner, http://vision.psychol.cam.ac.uk/jdmollon)

However, in southern Nigeria, where the fruit is called udala, it has become popular among adults, especially pregnant women, who believe it facilitates an easy birth.

Today, this species' broader potential is unexplored and the white star apple's value in organized commercial plantings remains untried. It deserves better. An important feature is that its fruit comes available in the dry season, a time when all too often there is not enough to sell or eat.

In parts of West Africa, seeds are occasionally collected and their oil extracted for soapmaking or cooking. Latex is also tapped from the trunk and used as rubber. The bark and tender leaves have medicinal applications. Local dancers use the hard, sharp, beanlike seeds in rattles. Easy to saw and plane, the brownish-white wood nails well, takes a fine polish, and is highly sought for construction work, tool handles, and much more.

(Sapotaceae) as Central America's chicle tree, the original source of chewing gum.

African Star Apple

This tall West and Central African tree (*Chrysophyllum africanum* A. DC or *Chrysophyllum delevoyi* De Wild.)[5] is found from Sierra Leone to the Congo basin and Angola. Its fruits have an apricot color and a pleasant acid pulp that is much esteemed. Although children scavenging the hillsides grab most of them, enough surplus occurs that they are sold in both rural and urban markets and eaten with relish by many adults. Across most of its range there are no organized plantings. However, in villages in Benin and southern Nigeria the tree is apparently deliberately cultivated.

Internationally, the species is known for its top-grade timber, marketed under the name longhi (or longui) rouge.

Milkplum

This small evergreen tree (*Bequaertiodendron magalismontanum* (Sond.) Heine & J.H. Hemsl.)[6] is distributed widely, from Guinea to Tanzania and from Nigeria to South Africa, where it is one of the more popular "veld fruit." Its bright scarlet, plumlike fruits have a pinkish-purple pulp of pleasant flavor. Women often collect large quantities, crush them in water, and boil the resulting extract with maize to produce a colorful and tasty porridge. The fruits are so relished that there are seldom enough on hand to meet the demand. Jam and jelly, not to mention vinegar, wine, brandy, and syrup, are also made. The jam—not unlike plum jam in appearance and flavor—is slightly, and deliciously, tart. It has been called "excellent."

The small tree, often hardly more than a shrub, is relatively drought-resistant and at least some types seem frost-hardy. It grows on many soils, but seems to occur most commonly on dry and well-drained slopes. In South Africa, for instance, it is found in ravines (kloofs) or small rocky hills (kopjies), notably in the Gauteng-KwaZulu-Natal region. The fruits cluster along the branches, hanging like small, bright-scarlet plums. Inside, they lack the segments and star-shaped arrangement of seeds. Instead, there is a single central seed. The fleshy pulp is rich in sugars and contains moderate amounts of vitamin C and minerals.

Regardless of its food value, this species is promising for protecting and improving stressed sites. It could prove useful, for example, in land reclamation, erosion control, and especially wind erosion reduction. Its use as a fruit crop in orchards or mixed cropping systems is as yet unexplored, but that also seems to be a promising line of investigation.

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[5] The taxonomy of this species remains somewhat murky. *Chrysophyllum africanum* (*C. delevoyi*) is so similar to *C. albidum* that it may be just a variety of it. *C. edule* Hoyle may be another synonym. Common names include omumu, alasema, or odara pear.

[6] Synonym are *Chrysophyllum magalismontanum* Sond and *Englerophytum magalismontanum* (Sond.) T.D.Penn. It is also called wild plum, stem fruit (stamvrug in Afrikaans), or red milkwood.

Although native to lowland tropical or subtropical climates, the tree is said to adapt to a wide range of environments and climatic conditions.

Forest Milkplum

This large tree (*Chrysophyllum viridifolium* J.M. Wood & Franks) is native to eastern South Africa (notably the Natal coast), Swaziland, and Mozambique. Its fruits are yellow and smooth with a yellowish-white pulp. They are shaped and sized like little apples, and are said to ripen irregularly throughout the year. Little else has been reported about them so far.

Milkwood

Found from the mountains bordering Zimbabwe, Mozambique, and Malawi as far north as the highlands of Cameroon, Uganda, and Kenya, this tall, stately montane-forest tree (*Chrysophyllum gorungosanum* Engl.) produces well-liked fruits. These large oval berries, usually containing four or five brown seeds and a milky pink flesh, have a pleasantly acid taste. They are said to make a splendid jam. Owing to the tree's height most are now accessible only to birds, bats, and monkeys. However, the species might make a useful cultivated crop. In orchard production or village plantings horticultural manipulation such as pruning could be employed to control the height and produce a reachable harvest.

Other edible-fruited African *Chrysophyllum* species, about which even less is known, include:

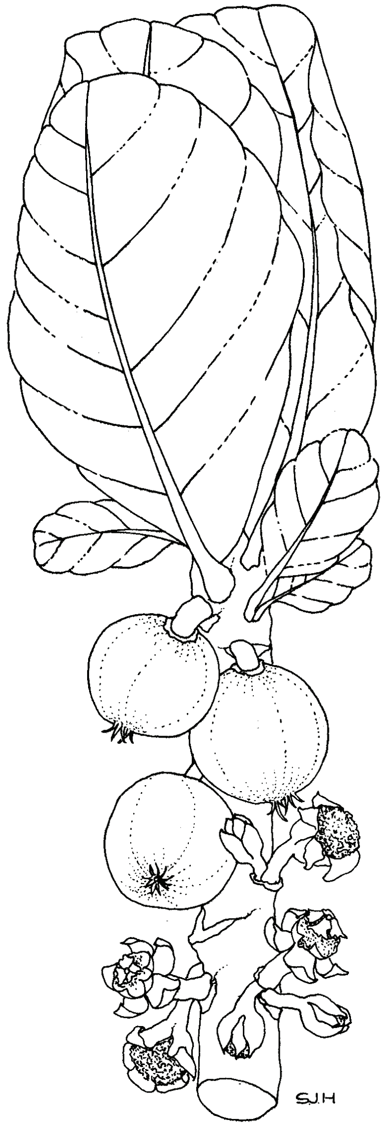
Chrysophyllum lacourtianum De Wild. Large, yellow, acid-tasting fruits the size of oranges. Found in West Africa, producing good timber.

Chrysophyllum natalense Sond. ***(Bequaertiodendron natalense*** (Sond.) Heine & J.H. Hemsl.***)*** The red fruits have a tart but pleasant flavor and are much enjoyed by humans and animals alike. Found in South Africa (Natal coast).

Chrysophyllum obovatum (Sabine & G. Don) Hemsl. Agreeable tasting fruits, the size of small apples. Found in Central Africa.

Chrysophyllum pruniforme Pierre ex Engl. Known as forcados star apple or Gabon plum, this tree bears yellow fruits the size of tennis balls. Found across West and Central Africa, it can be found at least as far eastward as western Uganda.


₦30
White star apple
(Chrysophylum albidum)
NIGERIA



Uapaca kirkiana

12

SUGARPLUMS

Africa is home to more than 30 species of wild fruit trees belonging to the genus *Uapaca*. Several produce fine flavored and attractive looking fruits that are in high demand in various parts of the continent. They are an African heritage that adds zest to traditional foods from porridges to desserts. But so far none has been accorded much—or even any—horticultural recognition.

This should change. These are promising resources for widespread cultivation. They are highly respected; farmers clearing land normally leave the wild groves standing. The public likes the fruits so much that in several countries an organized trade occurs, much as if the harvest came from orchards rather than wild stands. And in nature the trees seem fully at home on adverse sites where food production is generally poor. Indeed, because of that feature they have traditionally helped people survive famine.

Fully ripe, these typically plum-sized fruits are yellow-brown in color, juicy and honeylike in taste. They enclose several white seeds, each with a characteristic ridge along its back. Most are eaten fresh, but some are pounded with water and served as a refreshing drink. If left to ferment, this sugary liquid develops into a pleasant fruit wine. In addition, tasty snacks are made from the pulp by adding water, flour, and sometimes egg, flattening the doughy mixture into round cakes, and frying them.

Although little is known about these fruits' nutritional value, it is thought to be outstanding. The level of vitamin C can be especially high. In part, this is what makes sugarplums important foods in time of famine.

When left on the tree, fruits tend to ripen unevenly. Thus, although they can be picked up effortlessly from the ground, most are picked green and stored several days in the dark. They may be put into plastic bags or other containers. Commonly, they are placed in a shallow hole in the ground and covered with leaves from the tree. Other times they are placed in the village grain bins. In each case, they are exposed to ethylene, the fruit-ripening hormone, and they ripen evenly. Once ripe, they exhibit a good shelf life.

These valuable trees could be useful components of several cultivation systems, including backyard gardens or orchard-like plantings, as well as in agroforestry operations. They are ideal tools for projects proposing to protect soil and/or conserve habitats and native biodiversity. They are promising for

More than 30 species of wild fruit trees belonging to the genus *Uapaca* can be found across Africa. Several produce fine flavored, attractive fruits that are loved wherever they occur. These yellow-brown plum-sized delights add sparkle and zest to traditional foods from porridges to desserts. Fully ripe, they are juicy and honeylike in taste. Shown here is *Uapaca kirkiana*, near Vumba Junction, Zimbabwe. (B. Wursten, www.zimbabweflora.co.zw)

food security and poverty reduction enterprises. They seem suitable for public health initiatives aimed at balancing diets and reducing malnutrition.

But no one yet knows how to get the most out of the various sugarplum species. Indeed, so much remains to be done that the possible next steps seem overwhelming. From food science to soil science, opportunities for important advances abound on all sides.

Some might advocate that a deep understanding be given priority before anyone venture into growing these fruits on a bigger scale. That was, in fact, the opinion of one contributor, who felt "popularity on the market might little affect production." The view has merit, but as with other fruits highlighted in this book there are open opportunities for immediate amateur and professional endeavors that should not be dismissed out of hand. Indeed,

a collection of incremental improvements coming from many committed and observant people may produce faster progress than any laboratory or experiment station can deliver. Thus, in addition to formal projects, a sugarplum website might be created as a nexus for gathering and comparing information, catalyzing individual and team efforts, and sharing ideas and planting materials. And even small awards for special successes in research or promotional activities would likely stimulate dedicated investigations and outstanding developments far-exceeding any cash value of a prize.

Seen in overview, sugarplums need the same basic help as Africa's other outstanding wild fruit species. For one thing, wild resources need protection. For another, selection and perhaps breeding are needed to bring out exceptional fruits that are bigger, better, more attractive, and more valuable. Thirdly, promoting the fruits through individual, government, or group action can change attitudes toward a neglected food that has long been a traditional mainstay. And application of horticultural techniques can go far toward transforming sugarplums into crops. One specific horticultural feature to surmount is the trees' apparent tendency toward alternate bearing.

All in all, for food and health, these are worthy producers of quality fruits and, given improvement, are likely to produce far better ones than the forest fruits of today. Indeed, tomorrow's sugarplums could be astounding.

Species especially deserving of attention include the following.

Mohobohobo

The best known species (*Uapaca kirkiana* Müll. Arg.), this is one of the most popular wild fruits in the zone where eastern Africa meets southern Africa.[1] Throughout Zimbabwe, Zambia, Malawi, and Mozambique people like its sweet and pleasant taste, which is said to be somewhat reminiscent of pears. Vast quantities are eaten. Indeed, in some locations collecting parties, which may extend over several days and yield basketfuls of fruits, are organized for the enjoyment of everyone in the village. A very pleasant wine is made from them as well.

This is one of the few wild fruits with an organized distribution system. The districts where the trees grow send the fruits to distant markets. In Zimbabwe, for example, agents in Mashonaland, where the trees are abundant, truck enormous quantities of the fruits into Harare, where they are mostly sold by street vendors.

The tree producing these delights is a many-branched evergreen. Normally 5 to 6 m in height, it sometimes towers to 12 m. Commonly found on poor soils, it is often locally dominant on leached quartz sand and gravelly sites that are of little use for agriculture. In nature, it occurs mainly

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[1] Mahobohobo is a Shona name. Other names include wild loquat, mazhenje, muzhanje (tree), and masuku (Zambia and Malawi). In both Malawi and Zimbabwe, the name mohobohobo is also applied to white sapote (*Casimiroa edulis*), a fruit from America.

in open woodland at medium altitudes (trees have been reported as thriving at 700-2,000 m). It seems to grow poorly at low elevations, although that may be due solely to temperature. Indeed, the plant is so frost sensitive its presence is used as an absolute indicator of frost-free zones.

Fruits are borne in clusters close to the stem. Their hard skin reddens as it ripens. Although renowned for surviving in dry areas, the most succulent fruits are said to come from wetter areas, e.g., eastern districts of Zimbabwe, where the rainfall is fair, the land slopes, and surface water drains well. Fruit here is said to ripen evenly on trees and not to need any special treatment.

Mohobohobo is a nutritious food. The ripe edible part is especially high in vitamin C (1.8 mg per g of pulp)—higher even than guava.

It is not just Zimbabwe that admires these fruits extravagantly. In Zambia *masuku* are much sought after, and for part of the year they can basically underpin the diet. The fruits are also commonly seen across Malawi, although by default the trees generally occupy the drier and poorer soils.

Reportedly, certain trees have exceptionally sweet fruits. In addition, it has been said that most trees bear a particularly heavy crop every second year. This may reflect the genetic condition known as alternate bearing or may result solely from cyclical environmental stresses on the plants.

The timber is attractive, with a reddish color and fine grain. It works easily and takes a high polish. It is fairly resistant to termites, and so is used for construction purposes. It provides a good charcoal, also.

Uapaca heudelotii *Baillon*

This West African tree—an evergreen up to 30 m—bears strongly scented flavorful fruits containing three seeds. It extends from rainforest regions into wetter parts of the savannas. Throughout its range, people not only value the fruits, they revere the charcoal from the wood, considering it the finest of all. Goldsmiths and silversmiths throughout the area seek it out.

Uapaca nitida *Muell. Arg.*

A small to medium sized evergreen tree reaching 10 m or more in height, this widespread species is found in Central and southern Africa, including Congo, Burundi, Zambia, Zimbabwe, Mozambique, and Angola. Its ovoid fruits are three-celled and up to 2 cm long. When ripe, they are yellow-brown and tasty, but not as tasty as the mohobohobo, which overlaps its geographical range.

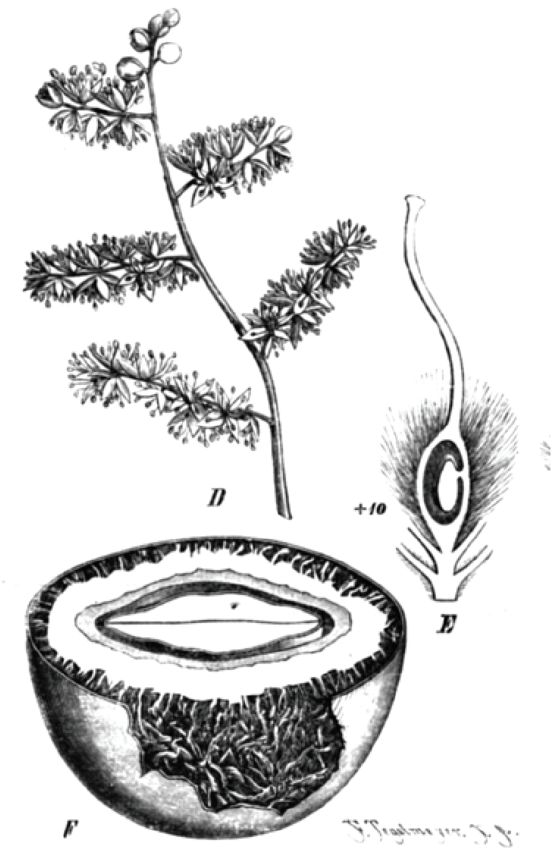
The wood is used for framing beds and as a structural timber. Charcoal made from it also has a high reputation.

Sugar Plum (Uapaca guineensis *Muell. Arg.*)

This fruit, with two distinct grooves, 3 to 4 seeds, and a sweetish pulp, comes from a forest tree of the Guinean savannas, extending from Sierra Leone eastward to the Central African Republic and Congo. It is most commonly found on steep slopes in open savanna woodlands, where the fruits are yellow or red when ripe. This savanna type is not highly esteemed, and seldom enters commerce. In the moist forest, however, the fruits are yellow, larger, fleshier, and much sweeter. Those forest types are sold in markets. In the unripe state they are also used as a cough medicine.[2]

An evergreen tree growing up to 30 m tall, this species produces a reddish timber whose many lines and intricate figures make it very attractive. Hard, durable, and a respectable cabinetmaking wood, it has been called a fine substitute for oak.[3]

[2] Information from P. Kio.
[3] This is not southern Africa's *Uapaca guineensis*, a rare swamp forest tree now designated *Uapaca lissopyrena* Radcl.-Sm.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SWEET DETAR

Throughout much of tropical Africa the tree called detar (*Detarium senegalense* J. Gmelin)[1] is common and its rounded pods are well known. It occurs in two types. The so-called forest type is tall (to 40 m) and has reddish pods whose yellow pulp tends toward bitter and inedible. The so-called savanna type is much smaller (5-10 m) with brownish pods whose greenish pulp makes good eating. At first sight fruits of the latter type look like apricots, but physically they are more like tamarinds with a crisp shell enclosing a rather flaky pulp and a single seed. These are what are known as "sweet detars."[2]

As with tamarinds (see part 1 of this volume), sweet detars are especially enjoyed in West Africa. Most are eaten fresh, but some are dried in the sun and sold in markets. Although sweet detars are today eaten largely by children, they have potential throughout society. The hard shell and dry pulp give them an exceptional shelf life and the sweet-and-sour flavor appeals to all palates.

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[1] The savanna form is these days usually classified as a separate species, *Detarium microcarpum* Guillemin & Perrottet, which we treat jointly here. For taxonomic details see Berhaut, J. 1967. *Flore du Sénégal*. 2d ed. Clairafrique, Dakar.. In this treatment, *D.* s*enegalense* has 10-13 leaflets; foliate stipules; 15-25 translucid points between 2 lateral veins; and a tomentatious calyx. By contrast, *D.* m*icrocarpum* has 7-10 leaflets; 40-50 translucid points between 2 lateral veins; and a glabrous or glaborescent calyx. (See also Lock, J.M. 1989. *Legumes of Africa: a Check List*. Royal Botanic Garden, Kew.)

[2] Other English common names include tallow tree, dattock, and dittock. Although sweet detar is little known to science, the tree and its fruit have an abundance of names in languages across western Africa. The following list is far from inclusive. *Arabic*: abu leita, abu leila; *Amharic*: gudi; *English*: sweet detar, sweet dattock (*D. microcarpum*), tallow tree (*D. senegalense*); *French*: détar, ditax, detah de Sénégal, niey datah, datah ney, boiré; *Wolof*: ditah (*D. senegalense*); dank (*D. microcarpum*); daha, dak, detax, detakh, ditakh, ditarh, wanta; *Serer*: ndoy (*D. microcarpum*); *Bambara*: bodo (*D. microcarpum*); *Mossi*: kaguédéga (*D. microcarpum*); *Hausa*: tsada (*D. microcarpum*);*Igbo*: ofo (*D. microcarpum*);*Hausa*: taura (*D. microcarpum*); *Kanuri*: gatapo (*D. microcarpum*); *Nupe*: gungorochi (*D. microcarpum*); *Tiv*: agashidam (*D. microcarpum*); *Jola*: bugungut, butchanjack, boubounkoute, fulibehen, mounhayona; *Mandika*: bodo, mamboda, taba, taleo, tallo saranokke, woko; *Fula*: boto, boto-burareh, botomel, dile, karkehi, konkehi, mobdey

Although normally consumed out of hand, sweet detars are also processed in different localized ways. In northern Nigeria, to mention just one locale, they are mixed with other fruits,[3] and boiled, strained, and concentrated into a sweetmeat resembling fruit leather. In Sierra Leone, they are made into refreshing drinks. One interesting feature: if a ripe fruit dries out, it can be revived by a soak in sugar water—the result being eaten as if it were freshly picked and the liquid being used separately as a fruity drink.

Sweet detar is an outstanding source of vitamin C—perhaps the finest of all. In 1988, researchers studying 29 fresh fruits consumed in Senegal discovered it to be the richest in vitamin C (up to 1,180 mg per 100 g). Nothing else came close.[4] One analysis of the pulp showed it about half sugar, with about 20 percent fiber, 4 percent protein, and 2 percent fats (on a dry-weight basis).[5]

Botanically speaking, this species, a legume, is related to tamarind. It produces equally vast quantities of fruit—indeed, the tree sometimes becomes almost enshrouded in dangling pods. Robust and resilient, it is a candidate for reforestation purposes. Although leguminous, it is probably not nitrogen fixing. Like tamarind, carob, and honey locust, it belongs to the Caesalpinioideae, a subfamily whose species usually possess few or no nodules, let alone rhizobial bacteria. Nevertheless, it survives in harsh and infertile sites and it tolerates some drought and much heat.

All in all, sweet detars seem likely to make good backyard-, village-, and street trees, providing welcome shade and copious food. Among its other useful outputs are the following:

Seeds The purple-brown, sweetly scented seeds have edible kernels. To extract those kernels, the fruit is broken open, the seeds are boiled for an hour, and their seedcoats removed. The resulting naked kernels are normally pounded into powder. In part of southern Nigeria this *ofo* flour is commonly added to egusi soup or cooked separately with leafy vegetables.[6] It is notably nutritious, having about 12 percent of a protein that is rich in the amino acids lysine and tryptophan.

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[3] Notably jackal berry (see Ebony chapter) and black plum (Chocolate Berries chapter).

[4] It was followed by baobab at 165 mg per 100 g (see Baobab), guava (156 mg), and cashew (150 mg); both guava and cashew are tropical-American in origin. Diop, P.A., D. Franck, P. Grimm, and C. Hasselmann. 1988. High-performance liquid chromatographic determination of vitamin C in fresh fruits from West Africa. *J. Food Compos Anal.* 1(3):265-269. It should be noted, however, that detars vary in their vitamin C content, depending on their level of sourness, with some exceeding 1,200 mg per 100 g.

[5] Favier, J-C., J. Ireland-Ripert, C. Toquc, and M. Feinberg. 1999. *Répertoire Général Des Aliments: table de composition* (2nd ed.). Le Centre Informatique sur la Qualité des Aliments (CIQUAL), Maisons-Alfort cedex, France.

[6] It is eaten notably with leaves of *Pterocarpus*, tree legumes that produce tasty leaves and some of the world's great timbers. Egusi and egusi soup are dealt with in the companion volume on African vegetables.

Sweet detar keeps well, and this traditional fruit could soon become available not just in regional cities but places far away from home. Although most sweet detar is still eaten fresh from the tree (especially by children), entrepreneurs in West Africa are bringing it to market in juices, extracts, purees, jams, dried fruit "leathers," and even as a "paté" with other fruits. (Amadou Malé Kouyaté)

The kernels are also crushed to extract their oil for culinary use. The solid residue remaining from this process is employed as animal feed. The seeds are also fashioned into ornaments. Indeed, they are commonly beaded onto strings to form necklaces that exude their own natural fragrance.

Wood The trees furnish excellent timber. Often called "African mahogany" (a name applied to other woods as well), the heartwood is dark, reddish-brown, and very heavy. Hard yet easily worked, it has a fine and regular grain and is eagerly sought for carpentry, joinery, and other premium purposes. It resists moisture, weathering, borers, and termites, so it is also prized for houses, boats, and fences, not to mention firewood and charcoal.

Resin If damaged, the bark exudes a sticky, pleasantly scented gum used to fumigate clothes and huts, especially in hopes of banishing mosquitoes.

For all its utility, this tree remains a wild plant. Presently, it is unknown in intensive plantations, or even in extensive village plantings. Rather, it occurs in outlying forests or farm fields where scattered specimens remain from the days the land was cleared. The wood is much sought-after, but neither sweet detar nor the several other *Detarium* species has yet been

accorded much silvicultural investigation. Now is the time. As a legume, it is tolerant, adaptable, generally reliable, and relatively insensitive as to site, soil, altitude, heat, or humidity. Silvicultural success could catapult into widespread use a new forestry resource that reduces malnutrition and contributes to rural development while it grows a great timber.

PROSPECTS

Because sweet detar is among the least understood of Africa's useful trees, projecting its prospects is difficult. However, the following seem to be reasonable expectations:

Humid Areas Uncertain but probably good prospects. Although unreported from locations where rainfall and humidity are high, the tree should thrive there (absent any particularly devastating pest or disease). It could possibly become a viable resource in all locations where tamarinds grow. Prospects seem especially good in Senegal (notably in the tropical province called Casamance), Gambia, and Sierra Leone where local interest in sweet detars is especially high. In those and the nearby countries the trees are carefully preserved whenever land is cleared.

Dry Areas Excellent prospects. These are climatic zones where detar finds its greatest humanitarian prospects. All trees providing resources in these hot, dry, exasperating locales will be welcomed as a boon.

Upland Areas Fair prospects in limited locations. Today, no one can say for sure just how well this untamed tree will do beyond its geographical home in the tropical lowlands. Certainly, however, it deserves testing at altitude, but only where temperatures remain well above freezing.

NEXT STEPS

To boost sweet detar into its rightful place in the food-resource base several initiatives can be envisaged. Most are suited to small-scale local actions because they require determination and intelligence more than international intervention, elaborate facilities, or academic perfection. Following are examples.

Survey the Scene First, people throughout tropical Africa (particularly West Africa) should assess local forests and fields and evaluate the various detar trees for productivity, genetic differences, pests, diseases, soil types, fruit quality, and other economic variables.

A mature sweet detar on the St. Augustine Campus of the University of the West Indies. Robust and resilient, sweet detar is a candidate for reforestation purposes. This legume survives in harsh and infertile sites. All in all, it seems likely to make good backyard-, village-, and street trees, providing welcome shade and environmental benefits, not to mention highly nutritious food.
(Pat McGaw, Friends of Botanic Gardens of Trinidad and Tobago)

Preservation and Genetic Selection Second, in-depth germplasm collections should be made to preserve any unique diversity discovered. The edible types to be found in different parts of Africa, for example, could be collected together and compared for sweetness. Over time, the best should then be formally identified and propagules disseminated for further tests. Those plants showing the most horticultural promise can subsequently be further propagated, perhaps by vegetative means; if they exist today, so much the better.

Information Exchange Third, the traditional means of handling, processing, marketing, and eating the fruits should be reviewed. The use of the various byproducts—resin, root-sugars, seeds, and seed oil—should also be detailed. This will create the baseline of knowledge whose lack now holds this crop back. Sharing this information electronically is now easy.

Nutrition As of now, no one knows just how good a food it is. Other than the outstanding vitamin C measurements, little nutritional information is

readily available. Detar pulp contains sugar and other carbohydrates, but portions may vary wildly. Chemical analyses and nutritional research could quickly tell much.

In a related vein, tests should be run to answer lingering uncertainties over toxicity. Of possible special concern are small, abortive, galled fruits that sometimes appear. They are unlikely to be mistaken for normal fruits, but they are rumored to be harmful.[7]

Horticulture Preliminary investigations reveal that the species can be propagated by budding.[8] This discovery enhances prospects of domestication and multiplication. Therefore, attempts via bud-grafting could be made to grow sweet detar in provenance trials in different parts of tropical Africa. Comparing various types under different environments will provide the means for evaluating their relative performances relatively quickly. Also, for any obviously promising plants bud-grafting could even now be used to develop exploratory commercial plantations.

Plantings The species should be immediately tested as a landscape tree, regardless of the food value of the best-looking types. Detar is a beautiful tree, hailing from the homeland of the tamarind, and perhaps could also help shade and enliven many a now-sun-scorched and dreary vista. Tests of this possibility for making life in the tropics more bearable should be mounted. If the trees in such plantings produce great fruit, so much the better.

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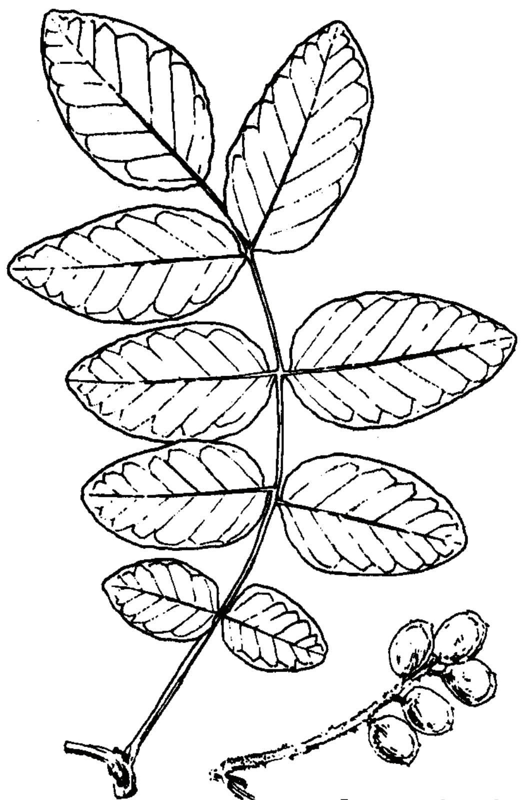
[7] If taken in excess they are reputed to cause vertigo. However, a contributor notes that: "There is no data! It is all hearsay so far."
[8] Information from J.C. Okafor.



Lannea discolor

14

TREE GRAPES

About 40 different trees belonging to the genus *Lannea* are about equally divided between the tropics of Asia and Africa. The Asian species have received some horticultural assessment, but the practical literature tells little about the score or more native between Madagascar and Senegal.

Yet out of these African species perhaps a dozen merit consideration as future food resources. Wherever they occur their fruits are avidly eaten; some already play a part in commerce. In West Africa, for instance, people commonly sell them both in city markets and along rural roadsides—a feature to be witnessed in and around Ouagadougou, for example.

Although *Lannea* belongs to the Anacardiaceae, the same family as mango, cashew, and pistachio, the fruits are more like grapes. They come in pendulous bunches and are reddish, purple, or black, with a whitish bloom on the skin. Although some have a resinous taste, many have a pleasant flavor commonly described as "grape-like."

In other ways, however, lannea fruits differ greatly from grapes. They are borne on trees, not vines. Most are much smaller than today's cultivated grape—being about 1 cm long at full ripeness. Each is capped at one end with three or four little "horns," the remains of the flower's styles. And inside, one finds a central stone. Indeed, botanically speaking, they are more like plums than grapes, and are classified as drupes, not berries.

The trees themselves seem conducive to cultivation. They are resilient, tolerant of drought, and often occur naturally in harsh sites, including some in which the human inhabitants have few food options.[1] They resist burning; the ground fires that are so prevalent and so destructive in the savannas leave them undamaged. The flowers attract bees in such numbers that beekeepers fight to hang their hives amid the branches.

Like the grape of international commerce, African tree grapes have multiple uses. They make a very good jam. Their juice is fermented into

[1] In parts of the Horn of Africa, the roots of some *Lannea* species (mostly *Lannea triphylla*) are often considered more important as food than the fruits. After the rains come, but before anything has grown to eat, these *Lannea* roots swell to become juicy and tasty. Digging the roots can destroy the tree but save lives, and some efforts have begun to turn this desperation food into a sustainable resource.

Tree Grapes. Although in the same plant family as mango, cashew, and pistachio, tree-grape fruits show their grape-like form. They also hang in bunches like grapes. And when ripe they are reddish to purplish-black skins with a whitish bloom. Perhaps most intriguing, many have a pleasant flavor described as truly "grape-like." These are thought to be *Lannea microcarpa*, photographed at Malamawa Jibrim, 13 km southwest of Zinder, Niger. (Josef Garvi, Eden Foundation)

"wine." They can be dried like raisins and safely put aside for later use. And those "tree raisins" themselves can be fermented into a beverage—an often-all-too-potent beverage.

Even when the fruits are unwanted, these trees are useful. They coppice well and sprout with vigor if the branches are cut at the proper time of year. This makes them useful for live hedges. The bark yields a water-soluble edible gum and a reddish-brown dye, as well as a fiber used among other things for cordage. The living trees also provide poles and floats for fishing. Oil from the seed kernel is used for soap and unguents.

These versatile wild resources are well worth exploratory research. Tree grapes are plants that could especially reward adventurous botanists, horticulturalists, and ethnologists. For plant physiologists and pathologists they present some fascinating mysteries. For horticulturists, their selection and growth requirements are complex enough to challenge the best minds. And anyone succeeding in overcoming these plants' problems will reap the satisfaction of having created crops capable of contributing to the health and wealth of some of the world's most destitute corners.

Whether any of these species have a future in substantial cultivation, or even in enhanced production in the wild, is unclear. Finding out is important. One first step might be the documentation of traditional usages. As the plants are already widely known, information on the various local ways of using it will enable an assessment of their continent-wide potential. Nutrition research and consumer trials could complement this local-uses information. After the plants' baseline information becomes better known, the practical research and development activities can be undertaken with more confidence. Also, it will then become easier to carry out awareness campaigns leading to greater popularity, improved production, and perhaps new profit in terms of subsistence and income.

Certainly, it will not be easy to advance these resources. Tree grapes are notoriously difficult to propagate vegetatively.[2] This poses a problem because plants grown from seed take years before they start flowering, and growers must wait an inordinate time before learning whether an individual tree is male, female, hermaphrodite, or hermaphrodite-but-functionally-female, and whether the fruit is worth eating. The adventurous souls who address such challenges typically plant groups of seeds, and then later rogue out all of the unwanted types. This is wasteful of time, effort, and money, and is unlikely to ever be widely adopted in everyday practice.

One advance that would make everything else more successful is the selection of types that provide the best eating. Such genetic selection yet awaits the dedicated, observant, and practical pioneers.

Following are brief descriptions of the best-known species.

Lannea edulis (Sond.) Engl. The "wild grape" of the southern half of tropical Africa[3] is a common and well-liked fruit that grows on what has been called an "underground" tree. The mass of this amazing plant is mostly buried out of sight beneath the soil. The subterranean trunks, often as thick as fenceposts (13 cm in diameter), creep along just beneath the surface. The branchlets bearing the leaves, flowers, and fruits stick up only slightly (3-30 cm) above ground. The whole tree nonetheless can be very big. A single specimen may cover many square meters, but disguised in the dirt, its massive size is seldom realized. In addition to its self-burying trunks, a deeply penetrating root system anchors the tree and endows it exceptional survivability under drought stress.

Moreover, this is not the only unusual botanical feature of this strange species. At the end of the dry season, bunches of small flowers pop out

[2] Information from J.D. Carr.

[3] It is known, for example, in South Africa, Botswana, Namibia, Zimbabwe, Zambia, Malawi, Angola, and Congo. In Zambia and Zimbabwe, it is a common shrub of woodland and vlei margins on the high veld. The trees are often so inconspicuous as to be noticeable only in land cleared for cultivation.

directly from the leafless stems, each bunch hanging from the bare wood and looking for all the world like creamy-yellow tinsel sprinkled over the land. People like these almost magical flowers, which are harbingers of the rains and of the better times soon to arrive.[4]

Later, the fruits begin forming. Eventually, they hang in grape-like bunches almost touching the ground, ripening slowly from pink through scarlet to wine-red and eventually black. Inside their thin skin is found smooth green flesh and a bean-shaped stone. In most the layer of pulp is thin, but whatever there is normally is juicy and pleasantly sour. They are exceptionally popular, particularly with children. Throughout much of southern Africa, kids squeezing tree grapes between their fingers and shooting the pulp into their mouths is a common sight.

Lannea discolor (Sond.) Engl. The plant known as "live-long" is also from the southern regions, but it grows in the normal fashion above ground. It is common in open grassland, bush, and woodland from Swaziland and South Africa (Gauteng) to northern Namibia, Mozambique, Botswana, Zambia, Zimbabwe, and Congo. It is deciduous and grows above ground, reaching 15 m in height. It is one of the first trees to drop its leaves as the rainy season winds down.

Interestingly, this is one of the few plants of any kind that are established by planting branches.[5] The ends of even large limbs are jabbed into the soil, where they strike new roots and flourish. In this manner, people get living fenceposts—hence the name "live-long." Several cultures revere these trees, believing them to be favorite haunts of ancestral spirits.[6]

The fruit is reddish to purple, and merely the size of a pea. It has a pleasant grape-like flavor, and is popular. At least in Zimbabwe, the plants flower in spring and normally fruit before the onset of the main rains.[7]

Lannea microcarpa Engl. This tree grape of western Africa is enjoyed for both its fresh fruits and dried "raisins." In either form, it is mostly boiled up into a sweet beverage. Particular types (sometimes designated as a separate species, *Lannea oleosa*) are apparently raised as a fully domesticated fruit crop in certain parts of West Africa. Indeed, this resource is even now of

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[4] Although the flowers normally come before the rains and the leaves after, it is not unusual for both to appear together.

[5] This process of planting large woody cuttings may be more practical than professionals have assumed. Today, with the availability of rooting hormones and a desperate need for trees, the possibility of planting branches deserves a thorough exploration. Not only would it create "instant forests," but it might circumvent hazards that take out tree seedlings, and thereby dramatically raise reforestation's success rate (now miserably low in all too many locations).

[6] Swazis call it "the tree of forgetfulness," believing it to harbor benevolent spirits who reconcile any enemies that meet in its shade.

[7] Information from Ray Perry.

commercial importance. It is widely consumed in Burkina Faso, for example, and the tree is often seen cultivated in and around villages. It grows to 15 m tall, and because of the shade and tasty bounty it is typically protected when farmers clear wood from future cropland.

And there are other useful products as well. The seed comprises a thin shell surrounding a kernel, whose copious oil is sometimes used to make soap or skincare products. The young leaves are edible and nutritious, containing 18 percent protein and 5 percent minerals. Cattle as well as passing humans commonly “browse” the foliage. Also, an edible (and soluble) gum exudes when the trunk is damaged.

Lannea acida A. Rich. Notably common from Senegal to Niger and Benin, this West African tree grape is found as far to the east as Cameroon and the Central African Republic.[8] A tall tree (up to 18 m), it occurs chiefly in the untouched bush far from villages. Its berry-like fruits (about 1 cm across and 1.5 cm long) occur in large clusters. Red to purple in color, they are popular and are consumed either fresh or dried. In dried form they look like currants and can be stored for use months later. To the tastebuds, the fresh fruits are slightly acidic and somewhat resinous. Both fresh and dried types are widely eaten and both are also fermented into drinks reminiscent of apple cider.

The tree has only a brief fruiting period, but this coincides with the months when other foods—especially nutritious foods—are scarce. The young leaves are also edible, and they develop even before the rainy season begins. Both features help allay vital food-security fears.

The plant tolerates dry soils but apparently requires either moist sites or annual precipitation of at least 600 mm to yield fruits well. It has above-average fire resistance, a critical feature in savannas where summer ground fires devastate any sensitive species.

Although not cultivated on an organized basis, this tree grape can be deliberately planted and it grows well under human care. Prior to planting the seeds need a good soaking in warm water. A 2-minute acid bath, followed by washing and soaking 12 hours in water, is also recommended.[9] The seeds then germinate well in soil-filled plastic bags. In the nursery, protection against rodents is necessary. The plant is dioecious, so to produce fruits a few males must be interspersed among many females.

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[8] It is called variously npekuni (Bambara), bembo (Mandinka), peguhi, bembey (Fula), sabaga, sabgha (More), and sonn (Wolof).

[9] Bellefontaine, R. 1995. Synthèse des espèces des domaines sahélien et soudanien qui se multiplient naturellement par voie végétative. Pp. 95-104 in d'Herbès, J.M., J.M.K. Ambouta, and R. Peltier, eds, *Actes de l'Atelier “Fonctionnement et gestion des écosystèmes forestiers contractés sahélien”, Niamey, Nov. 1995.* ORSTOM - CIRAD - Ministère de l' Agriculture, Niamey.

Whether other African tree grapes have any merits is uncertain. Among those recommended to us are the following.

Lannea grandis. (Dennst.) Engl. West Africa. Shrub of the forested savannas.

Lannea alata Engl. Tropical Africa. Fruits are edible. "Wool" stripped out of the root bark is used for padding and for stuffing mattresses.

Lannea fulva (Engl.) Engl. Shrub and tree to 20m tall.

Lannea gossweileri Exell & Mendonça Tropical Africa, including Zambia, Congo (Katanga), Angola, and Namibia.

Lannea kerstingii Engl. & K. Krause Tropical Africa.

Lannea velutina A. Rich. Western tropical Africa (Senegal to Ghana). Shrub or tree to 15 m. Fruit edible, foliage browsed.

Lannea welwitschii (Hiern) Engl. West and Central Africa (Côte d'Ivoire to Uganda, as well Congo and Angola). Abundant in Cameroonian forests. The tree reaches 30 m. tall. Its small fruits (6-7 mm long) are blackish, viscous, and smell somewhat of turpentine. Regardless of that, they are widely eaten.

Appendix A

BIOGRAPHICAL SKETCHES OF PANEL MEMBERS

Norman Borlaug, Chair, is Senior Consultant to the Director General of CIMMYT (International Maize and Wheat Improvement Center), as well as Distinguished Professor of International Agriculture at Texas A&M University, and President, Sasakawa Africa Association. A Nobel Peace Laureate, member of the National Academy of Sciences, and Founder of the World Food Prize, he is the recipient of nearly 60 honorary degrees. Dr. Borlaug's early work in plant pathology, wheat breeding, and agronomic systems has led him to become one of the best-known spokespersons and ambassadors for tropical agriculture and food security. Dr. Borlaug remains deeply involved in enhancing African agriculture through the Sasakawa Africa Association and its Global 2000 Partnership with the Carter Center, whose mission is raising the productivity of African farmers through sustainable development and equitable and responsible use of resources. Borlaug is from the U.S., and has a doctorate in plant pathology from the University of Minnesota.

Anthony Cunningham is Professorial Research Fellow at Charles Darwin University in Fremantle, and Director of People and Plants International, the follow-through to the WWF/UNESCO/Kew "People and Plants Initiative," which he helped found and for which he was African Regional Coordinator through 2000. An ethnoecologist whose work focuses on the applied ecology of natural-resource use by people, his early research was on traditional foods in southern Africa. Much of his research is tied to implementation processes promoting collaborative resource management programs between local communities and outside influences such as government, NGOs, and conservation or commercial interests. Cunningham is from South Africa, with a doctorate in botany from the University of Cape Town.

Jane I. Guyer is Professor of Anthropology at Johns Hopkins University, after moving in 2002 from Northwestern University where she was Professor of Anthropology and Director of African Studies from 1994. Professor Guyer, a Woodrow Wilson Fellow in 2003, specializes in African studies, social anthropology, and the study of production and distribution systems, in particular the anthropology of the economy and material life in West and Equatorial Africa. She focuses on the growth and change of indigenous economies, with a special emphasis on food economies and money management outside structured systems. Professor Guyer's most recent book is *Marginal Gains: Monetary Transactions in Atlantic Africa*, which focuses on the function of popular economic systems in Africa, from crisis conditions to ordinary household budgets. Guyer, a U.S. citizen, is from England, and has a doctorate in anthropology from the University of Rochester.

Hans Herren has been President of the Millennium Institute since 2005. Dr. Herren served as Director General of the International Centre of Insect Physiology and Ecology (ICIPE) in Nairobi for twenty years, prior to which he was with the International Institute of Tropical Agriculture. An agronomist and entomologist, Dr. Herren has spent most of his working life in Africa, where his research has been on the field-level union of science-led information with local production systems, particularly emphasizing pioneering applications of integrated pest management. His latest research efforts address poverty alleviation, sustainable agricultural productivity, and biodiversity conservation in Africa. Herren's contributions to improving Africa's food security, particularly research and control of the cassava mealybug through the world's largest biological control project, have been recognized through many awards, including the Tyler Prize for Environmental Achievement and the World Food Prize. A Foreign Associate of the National Academy of Sciences, Herren is from Switzerland, with a doctorate in agricultural sciences from its Federal Institute of Technology.

Calestous Juma is Professor of the Practice of International Development and Director of the Science, Technology and Globalization Project at the John F. Kennedy School of Government at Harvard. He is a Member of the National Academy of Sciences and the Kenya National Academy of Sciences, and Fellow of the New York Academy of Sciences and the World Academy of Art and Science. Dr. Juma is former Executive Secretary of the United Nations Convention on Biological Diversity and founding Executive Director of the African Centre for Technology Studies in Nairobi, an independent public policy research

institution. His research, beginning with field work with indigenous crops in Kenya, includes biodiversity and biotechnology, evolutionary and systems theory, science and technology policy studies, institutional change, and international trade and environmental policy. Dr. Juma has written widely on issues of science, technology and environment, including *Science, Technology and Economic Growth: Africa's Biopolicy Agenda for the 21st Century*. Juma is Kenyan, with a doctorate in science and technology policy studies from the University of Sussex.

Akinlawon Mabogunje was Chair of the Development Policy Centre in Ibadan, Nigeria until retirement, and serves as co-convener of the international Initiative on Science and Technology for Sustainability. He is also Chairman of the Nigerian Presidential Technical Committee on Housing and Urban Development. Formerly Professor of Geography, Dean of the Faculty of the Social Science, and Director of the Planning Studies Programme, University of Ibadan, he was also President of the International Geographical Union. Dr. Mabogunje served as Advisory Committee Chair for the Urban Management Programme of the United Nations Centre for Human Settlements and Vice-Chairman of the Directorate of Food, Roads and Rural Infrastructure, Office of the President, Nigeria. A Foreign Associate of the National Academy of Sciences, Dr. Mabogunje's work explores continuity and development of rural/urban/regional interactions in Africa over time, with increasing attention to future issues of sustainability. Mabogunje is from Nigeria with a doctorate in geography from University College London.

Barbara Underwood, Adjunct Professor of Nutrition (Pediatrics) at Columbia University, was until recently Scholar in Residence at the U.S. Institute of Medicine, and is Past President of the International Union of Nutritional Sciences. Prior to retirement she was Chemist at the National Eye Institute of the U.S. National Institutes of Health, where she also served a secondment as Scientist in the Nutrition Unit of the World Health Organization. Dr. Underwood has broad experience in international nutritional deficiency and maternal/child health problems, with recent work devoted to development of global policy and guidelines for the control of micronutrient deficiencies of vitamin A, iron, and iodine. Her laboratory developed and first applied in human populations the Relative Dose Response (RDR) test to indirectly identify depleted vitamin A stores. In addition, her research and training interests have focused on nutritional problems of mothers and children in deprived circumstances. Underwood is from the U.S., and has a doctorate in nutritional biochemistry from Columbia University.

Montague Yudelman has been involved in international agricultural development for close to 50 years. A Woodrow Wilson Fellow, he has also been a Senior Fellow at the World Wildlife Fund for Nature (WWF) in Washington. He was on the staff of the Rockefeller Foundation during the gestation of their international agricultural research program, and later Director of Agriculture and Rural Development at the World Bank. He has taught at Harvard University and the University of Michigan and served as Vice President of the OECD Development Center. He was Chair of the Board of Trustees of the Population Reference Bureau and serves on the Board of The Vetiver Network, among other organizations. He has published widely in the field of agricultural development, food production, and pest management, including the 1964 standard, *Africans on the Land*, and the International Food Policy Research Institute's 2020 Vision Discussion Paper (32) on *Integrated Nutrient Management, Soil Fertility, and Sustainable Agriculture: Current Issues and Future Challenges* (with Peter Gruhn and Francesco Goletti). Yudelman, a U.S. citizen, is from South Africa, and has a doctorate in agricultural economics from the University of California at Berkeley.

Appendix B

CREDITS

22	Thonner, Fr. (1915). *The Flowering Plants of Africa*. Dulau & Co. Ltd., London.
24	András Zboray, www.fjexpeditions.com
27	Laure Guerrini
31	Caroline Gullick
35	Caroline Gullick
39	Busson, F. (1965). *Plantes Alimentaires de l'Ouest African: Étude Botanique, Biologique et Chimique*.
40	*Food from the Veld*, Delta Books, Johannesburg
42	Jerry Wright
46	Kazuo Yamasaki
59	Baobab. *Adansonia digitata.* International Centre for Underutilised Crops, Southampton, UK.
60	PROTA, www.prota.org; redrawn/adapted W. Wessel-Brand
62	© Erick C.M. Fernandes, ecf3@cornell.edu,
64	© Erick C.M. Fernandes, ecf3@cornell.edu,
75	Thonner, Fr. (1915). *The Flowering Plants of Africa*. Dulau & Co. Ltd., London.
76	Gomera Schrader
78	Forest & Kim Starr, USGS
82	Cori Ham
87	University of Florida, Institute of Food and Agricultural Sciences (2004), http://edis.ifas.ufl.edu/he615
88	*Food from the Veld*, Delta Books, Johannesburg
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133 Ezemvelo KZN Wildlife, www.kznwildlife.com
134 *A Curious Herbal*, Volume II, Plate 329 (1739), Engraved by Elizabeth Blackwell
136 Karen Rei Pease
141 USDA image k7388-11, Scott Bauer
147 L. Van Houtte, *Flore des Serres et des Jardins de l'Europe* (1861)
148 *Food from the Veld*, Delta Books, Johannesburg
150 Peter Longatti
152 Madeleine Philippe
157 Glenn Kopp, Missouri Botanical Garden, glenn.kopp@mobot.org
163 Gerrit Schouten (1824)
164 *The Plant Kingdom Compendium*
166 © Roland Bischoff / botanikfoto
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220 Eden Foundation, Falkenberg, Sweden
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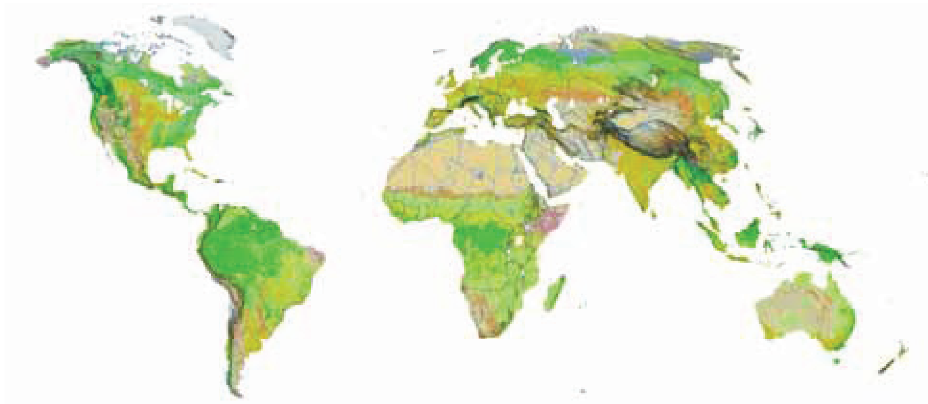
254 Willem van der Merwe
256 Yosef Mizrahi
261 FAO /Masquel Lasserre
262 *Food from the Veld*, Delta Books, Johannesburg
264 PhytoTrade Africa
269 *Food from the Veld*, Delta Books, Johannesburg
270 Köhler's *Medizinal-Pflanzen* (1887) (*Landolphia florida*)
272 Paul Latham
276 Roy Danforth and Paul Noren
279 *Food from the Veld*, Delta Books, Johannesburg

280 USDA, ARS, National Genetic Resources Program, *Germplasm Resources Information Network* (GRIN), www.ars-grin.gov/cgi-bin/npgs/html/taxon.pl?400240 (24 October 2007): Lynda E. Chandler or Karen Parker (*Icacina oliviformis*)
283 Marco Schmidt
289 USDA, ARS, National Genetic Resources Program, *Germplasm Resources Information Network* (GRIN), www.ars-grin.gov/cgi-bin/npgs/html/taxon.pl?400240 (24 October 2007): Robert J. Gibbons (*Icacina oliviformis*)
290 *Food from the Veld*, Delta Books, Johannesburg
292 Steve Flowers
294 © Top Tropicals
299 © Top Tropicals
300 FAO /Masquel Lasserre (*Vangueria infausta*)
302 Rihana Botha, www.ecoport.org
307 *Food from the Veld*, Delta Books, Johannesburg (*Vangueria esculenta*)
308 *Food from the Veld*, Delta Books, Johannesburg
311 Paul Latham
312 Claus Lipis
315 FAO /Masquel Lasserre (*Strychnos cocculoides*)
316 *Food from the Veld*, Delta Books, Johannesburg
318 Roy Danforth and Paul Noren
320 J.D. Mollon/Petroc Sumner, http://vision.psychol.cam.ac.uk/jdmollon
323 Pierre Guertin, www.geocities.com/aildoux/herbierphilatelique.htm
324 *Food from the Veld*, Delta Books, Johannesburg
326 B. Wursten, www.zimbabweflora.co.zw
329 Pierre Guertin, www.geocities.com/aildoux/herbierphilatelique.htm
330 Engelmann (ed.): *Natürliche Pflanzenfamilien, Vol. III, 3* (1891)
333 Amadou Malé Kouyaté
335 Pat McGaw, Friends of Botanic Gardens of Trinidad and Tobago
337 *Flore du Cameroun*, Museum National D'Histoire Naturelle
338 *Food from the Veld*, Delta Books, Johannesburg
340 Josef Garvi, Eden Foundation, Falkenberg, Sweden
345 Busson, F. (1965). *Plantes Alimentaires de l'Ouest African: Étude Botanique, Biologique et Chimique* (1965)
354 US Geological Survey Global Land Cover Characterization (Christopher Barnes), on Goode Interrupted Homolosine Equal Area Projection from ODT Maps-ODTMaps.com.



INTER FOLIA FRUCTUS
"Among foliage fruit"
Latin maxim